

Designing and Delivering Interactive, Simulator-based Aviation Research Studies on the Web

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Traditionally, interactive, simulator-based aviation research studies have been conducted in physical labs. However, the internet has allowed researchers to deliver experiments via web platforms, thus gaining the ability to reach out to larger populations, including subject-matter-experts. However, existing experiment delivery platforms are limited in delivering complex research studies. Such studies require multi-participant interaction, complex task environment, integration of standard experiment procedures with complex task environment, and a high degree of research controls over participant performance, selection, and data collection process. Such studies are often the ones that benefit the most from access to subject-matter-experts.

There is a lack of a distributed, customizable, plug-and-play, online experiment platform capable of delivering the aforementioned types of studies. To address this gap, a novel prototype web platform, called the Integrated Modular Platform, was developed. The platform was designed to meet all the aforementioned requirements of a complex research study through integrating a website component with any PC-based simulator system to allow researchers to provide a real-time distributed simulation environment to multiple participants.

A case study approach was used to provide initial validation of the developed platform and concept by using the Integrated Modular Platform to conduct a follow-up study on the effect of information asynchrony on pilot-controller communication. Information asynchrony describes the situation where the same piece of information is presented to two different parties at different times (Yuan & Histon, 2014). For the purpose of validating the platform, the platform was used to deliver a realistic ATC-flight simulator environment representative of the real world on the web, in combination with standard experiment procedures. As well, the Integrated Modular Platform was used to recruit subject-matter-expert participants to participate in the follow-up study, as part of demonstrating its ability to provide high research control. The result of the follow-up study showed that there were no generally observable effects on pilot-controller communication as information asynchrony increased. Factors that may have created this non-effect were identified and include challenges maintaining consistent operations with professional participants, and limitations in characterizing information asynchrony with time.

The result of initial validation of the Integrated Modular Platform from the case study demonstrated the capability of an online simulation environment to represent real-world work practices. A majority of participants had positive experience with the case study overall. The recruitment of subject-matter-experts was also generally effective in terms of screening for qualified personnel, with improvements needed for online scheduling implementation. The result showed that the Integrated Modular Platform has the proven capability to successfully provide both realistic simulation environments on the web, in terms of ATC-flight operations, and high degree of research control with subject-matter-expert recruitment. Future work include further validating such capability for different simulation environments and recruitment needs. As well, there is still the need to validate platform's ability to allow non-programming researchers to implement different types of complex research studies on the web, as this was not done in the case study.

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List of Acronyms

ATC – Air Traffic Control

OS – Operating Systems

SMEs – Subject-Matter-Experts

TRACON – Terminal Radar Approach Control

UAS – Unmanned Aerial Systems

Chapter 1

Introduction

Subject-matter-experts (SMEs) are a highly valued resource for human factor studies. Compared to non-expert participants, such as members of the general public, SMEs allow researchers to collect data reflecting professional insights and experiences. However, it can be difficult to bring these experts to a physical lab due to cost, distance, scarcity in the local population and professional job commitments. Furthermore, they often have non-standard work hours and the requirements to travel to places, thus making it difficult to match a schedule that they as potential participants and the experimenter can meet in a physical lab.

One way of addressing this difficulty is to provide both the experimenter and interested SMEs easier access to experiments through delivering experiments on-line on the web. The advantages of delivering experiments on the internet included: 1) reduced cost, 2) around-the-clock experiment availability, and 3) the elimination of travelling distances for participants. These advantages have made online experiments popular with researchers; Ulf-Dietrich Reips (2002a) found that "70% of the researchers who conducted a web experiment intended to certainly use the method again in future experiments, with the other 30% "maybe"" (p. 244).

Existing examples of online studies can be found on public online experiment web services such as web services hosted by educational institutions such as the one hosted by Hanover College (see <http://psych.hanover.edu/Research/exponnet.html>). Example topics included social perceptions (Shultz, 2015) and interpersonal relations (Kelly, 2015).

However, from a literature review on existing publications and online search for examples of experiments on the web, there appeared to be a lack of more complex research studies being delivered on the web. This thesis defines complex research studies as studies with experiments that require capabilities such as: 1) multi-participants interactions, which may include interaction with an experimenter as well, 2) a complex task environment requiring collaboration and professional skills, 3) integration of standard experiment procedures such as briefing participants, obtaining consent and administering questionnaires, and 4) a high degree of research controls over participant performance (i.e. session progress and performance monitoring), participant selection (i.e. login control, participant qualification and scheduling), as well as data collection process (i.e. specify what

data to collect and when). Such studies are often the ones that benefit the most from access to subject-matter-experts.

A majority of the experiments found online did not have these characteristics; rather, they were survey-type, autonomous single-participant experiments (Tuten, 1997; Taylor-Powell & Hermann, 2000; Reips, 2002b; Andrews, Nonnecke, & Preece, 2003; Birnbaum, 2004; Sue & Ritter, 2007). Therefore, this thesis describes the development and evaluation of a web platform called the “Integrated Modular Platform”, designed specifically for delivering complex human factor research studies online.

1.1 Opportunities and Challenges in Delivery Complex Research Studies Online: The Need for a New Platform

Experiments on the web allow standard experiment procedures such as participant briefings and consent forms to all be administered online through webpages, without the presence or the guidance of a mediator. In addition, experimenters have the ability to also monitor and analyse data at any time through management tools such as Microsoft Access Database (Cooper et al., 2006). Recent technological advances in the internet have also provided researchers the availability to use third-party services such as online survey and online conferencing for purposes such as e-learning (Xu, Yin, & Saddik, 2003), business advertisement (Mayer & Mitchell, 2012) and research interviews (Bertrand, Bourdeau, & Bourdeaufaulavalca, 2010). These services have allowed researchers the ability to conduct different types of research online.

Unfortunately, limitations to current web platforms may have contributed to the lack of more complex research studies being delivered online. For example, the majority of existing web platforms were either: 1) not designed for single and autonomous participant interaction, 2) did not have the means to replicate complex task environments, 3) did not integrate other experiment procedures with complex task environment as one package, or 4) were not easily instrumented to provide the full high research controls as previously described. Complex research studies often require all four capabilities listed above simultaneously. For example, a complex research experiment requiring a simulator component cannot simply use an online survey as delivery platform as it lacks the online communication or online simulation capability. Even with a web-based simulator component and capability for multi-participant interaction, replicating the physical lab experience online also

requires common experiment components, such as recruitment, participant qualification, document presentation, questionnaire-administering, scheduling, experiment controls and specific data collection. Thus, it was very difficult to use current web platforms to deliver complex research studies online, limiting the potential for these studies to reach out to SMEs.

To deliver more complex research study online, there was a need to develop a new web platform that addresses the need for these multiple capabilities fully as one complete package. Such a platform would be a set of codes that generates a series of webpages to deliver the workflow of the experiment for a complex online research study. Furthermore, the development of this platform may best be approached by taking maximal use of third-party web services that offer constantly-improving technologies by professional, full-time developers, instead of by researchers who are not experts in these areas to develop from scratch. This may also offer the potential for the platform to run different complex research studies, if the platform contains a set of technologies that can allow researchers to customize for specific needs of an experiment. This thesis describes the development and evaluation of such a platform.

1.2 Evaluating a New Platform: A Case Study of Information Asynchrony

In order to explore the suitability of the online experiment delivery platform being developed, a case study approach was taken. A representative example of a complex research study was an examination of the effect of information asynchrony on pilot-controller communication. Information asynchrony describes the situation where the same piece of information is presented to two different parties at different times (Yuan & Histon, 2014), as depicted in Figure 1-1. In relation to complex research studies, major requirements for this study included: 1) the presence of an experimenter, pilot and controller and communication between them 2) simulation of the complex air-traffic-control/cockpit environment, 3) integration of complex environment with standard experiment procedures, and 4) a high degree of research control over participant performance, participant selection, and data collection process. While the original study recruited non-expert students as participants, more insight would be gained by the use of SMEs, making a follow up study an ideal test case for evaluating the online delivery platform.

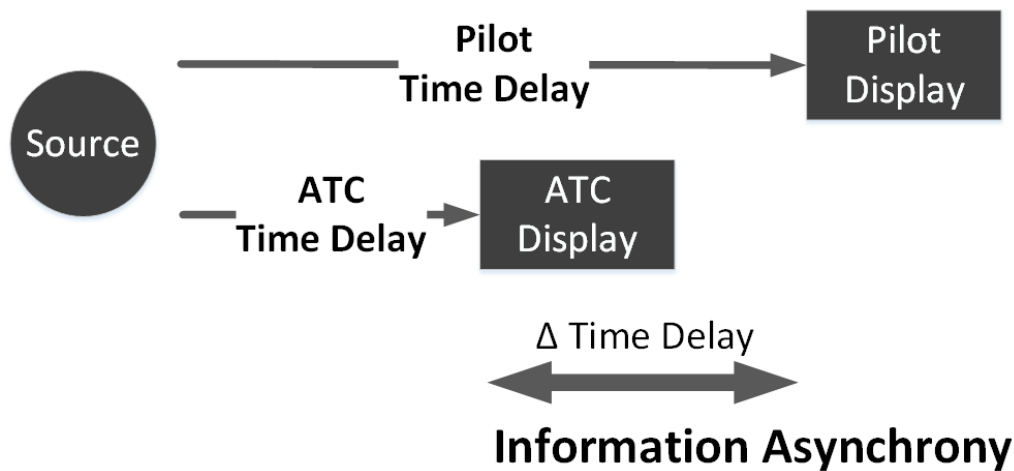


Figure 1-1: Information asynchrony diagram

1.3 Research Goals and Objectives

In face of the challenges that have been discussed so far in conducting complex research studies online, a new delivery platform that explores maximal use of multiple third party technologies seems to offer a potential to deliver complex research studies online. As well, it would offer the potential to address the identified limitations to current web platforms. As there can be many types of “complex research studies”, this thesis focuses on an interactive ATC-flight study as a representative complex research study. Thus, the research goal of this thesis is to: *“Identify key lessons learned through conducting an interactive ATC-flight simulator research study online using the web as delivery platform”*. In support of this goal, four objectives were established.

Objective 1: Develop a web-based platform suitable for delivering an interactive aviation complex research study online to SMEs.

Before any complex research studies can be delivered online, one must have a suitable delivery platform available. This objective was achieved by creating the codes for basic web application for this platform using ASP.Net framework language with HTML, CSS, JavaScript and server scripting. The web application would consist of a number of web pages incorporating multiple existing online technologies to deliver the capabilities needed for the purpose as described in this objective. As well, the needs of researchers with limited programming skills, but wishing to use this platform in the future, were also taken into consideration in the design.

Objective 2: Demonstrate the integration of third-party web services required for a complex human factors research study into the web-based platform.

This objective was fulfilled by identifying existing online technologies that provide capabilities required to deliver a representative complex human factors research study very similar in nature to the example as mentioned earlier in the chapter. The identification of these online technologies was achieved through an online research for available third party web-services and or open source codes for public use. The technologies were then integrated into the platform through a web-embedding technique. This objective was critical as these online technologies provided the core capability of the platform for a successful delivery of the said simulator study on the web.

Objective 3: Identify insights, implications and lessons-learned for online complex experiment delivery from a representative case study.

Here, the objective was achieved using a case study approach. A follow-up study to the preliminary study on information asynchrony conducted by Yuan & Histon (2014) was delivered on the web through the use of the developed web-based platform. Key lessons were then identified through a lessons-learned critique on several topics of interest in terms of participants' experience with the simulator, and recruitment of professional pilots and controllers as SMEs. The critique sought to uncover any insights, implications, and lessons-learned knowledge that were gained from author's observations and supporting data collected in the case study.

Objective 4: Identify any observable effect of information asynchrony on pilot-controller communication applied to non-cooperative surveillance data.

This objective was associated with the results of the follow-study on information asynchrony. Time delays were manipulated as professional pilot and controller communicated with each other to resolve a collision issue in a dynamic simulated ATC-flight operation environment. Data was collected objectively through measureable characteristics of communication breakdown, as well as subjectively through self-rated questionnaires.

1.4 Research Contribution

The contribution to the research community in achieving the aforementioned research goals and objectives lies in two major areas. The first research area was in regards to advancing online

research methodology on the web. This included solving the current limitations of existing platform to deliver more complex research studies on the web. This would expand the ability of researchers to deliver experiments on the web to wider variety of research studies and take advantages of the web environment as aforementioned. .

The second area was in the follow-up pursuit of investigating the human factor challenge with information asynchrony. These concern the larger research community as well as aviation community. The contribution is in demonstrating the potential of the online methodology to deliver a dynamic, aviation-based simulator on the web to replicate representative operations, such as a flight-ATC operation. This would point to more opportunity to not be confined by limitation of a physical lab location, and thus increase the potential to recruit professional participants (i.e. professional pilots and controllers) internationally. The follow-up study itself would also contribute to the larger research community by showing how increases of information asynchrony can affect operator communication during collaborative operations such as an ATC-flight operation.

1.5 Thesis Organization

The remainder of the thesis is organized as follows:

Chapter 2: Background. This chapter presents an overview of online experiments delivered on the web as well as a literature review of previous works by researchers on internet-based experiments. As well, this chapter presents a discussion on the definition of complex research studies and uses online search results to support the observation of a lack of such studies being currently delivered online.

Chapter 3: The Integrated Modular Platform. This chapter describes the design process of the platform through three major design considerations, the technical details and conceptual model of the design, as well as presenting examples of the resulting implementation.

Chapter 4: Design of a Case Study Evaluation of the Integrated Modular Platform. This chapter presents the background and experimental methodology of the representative case study used as an initial demonstration of the Integrated Modular Platform. A review on previous works of information asynchrony study is presented in this chapter, followed by a discussion on the design of the information asynchrony experiment. The case study leads to the lesson-learned critique as presented in Chapter 6.

Chapter 5: Results of Follow-up Study on Information Asynchrony. This chapter presents the data analysis and results of the follow-up study on information asynchrony. This fulfils the goal of Objective 4.

Chapter 6: Lessons-Learned Critique on the Integrated Modular Platform: This chapter presents the learned-learned critique on two major areas of the case study looking at: 1) participants' experience with an interactive, simulator-based research study delivered on the web, and 2) subject-matter-expert recruitment. The purpose of the critique was to provide key lessons learnt useful for future researchers to consider when using the web as a platform to deliver complex research studies online.

Chapter 7: Conclusions and Future Work: This chapter summarizes how the objectives were achieved, the key findings in this thesis, and thesis contributions to the larger research community. As well, future work is proposed here.

Chapter 2

Background

This chapter presents the background material on online experiments delivered on the web. It introduces important concepts in terms of architecture, techniques, and comparison between lab-based and online web-based experiments. A review of previous works on web-based experiment is covered. As well, a review of the capabilities of existing web-platforms, as of 2015, is presented to assess the existing capability to deliver a complex research study, such as an interactive ATC-flight simulator research study, on the web.

2.1 Methodology

Past publications and existing examples of online experiments on the web were reviewed. Sources included books and journals of various research disciplines on topics related to using the internet as a research tool. Books reviewed included those on the topic of internet research methodology as well as web development. Birnbaum (2000) and Menon (2002) provide compilations of much of the previous work done by pioneers of internet research methodologies. Journal sources reviewed included International Journal of Internet Science, American Economics Review, Journal of Economics Behaviour and Organization, Journal of Medical Internet Research, SAGE Journals, and Simulation Practice and Theory. Google was used to search for examples of online experiments delivered on the web using terms such as “online experiments”, “online research studies”, “online aviation studies”, “web-based experiments”, “web survey experiments”, “collaborative web-based experiments”, and “interactive web-based simulation experiments.”

2.2 Overview of Web-Based Experiments

The term “web-based experiments” has been widely used to describe experiments delivered via the web (Reips, 2002a). While the web has been the most widely-used platform for its high accessibility and popularity to date, other platforms that were utilized (but rarely in comparison to web platforms) included emails, file transfer services or online net-chatting services (Reips, 2002b). At a high-level, web experiments are a data-collection process involving client-server interaction on the web as described in Figure 2-1.

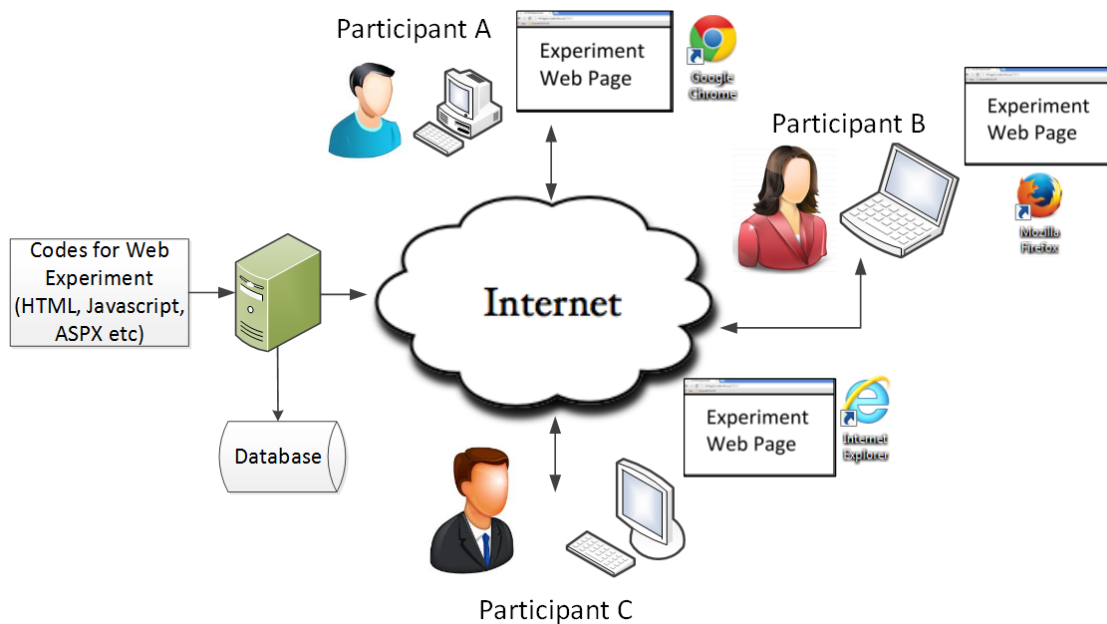


Figure 2-1: Participant – web experiment interaction

The web browser on the participant’s computer represents the client side with browsers requesting and displaying the experiment in the form of webpages on the internet. One can have multiple “client sides” as multiple participants can interact with the web experiment simultaneously. The server side represents the experiment webpage, with codes stored and delivered online (hosted) by a server machine. The machine can be a computer owned by the researchers, or by third-party for research purposes. Figure 2-2 describes the client-server interaction.

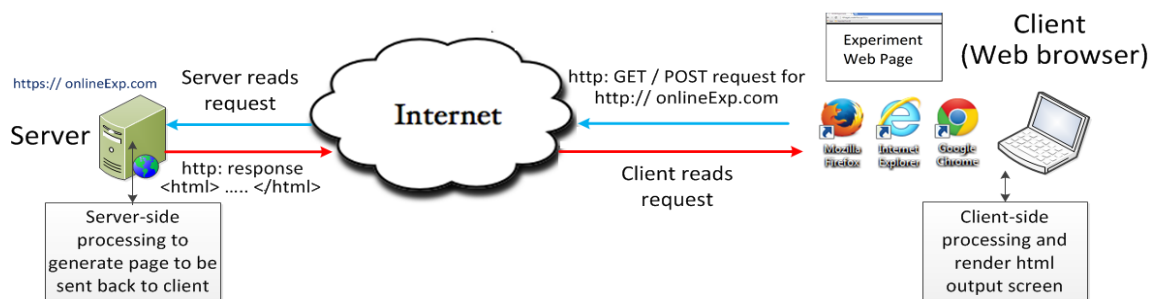


Figure 2-2: Server machine – web browser interaction

A participant opens up his or her web browser on the internet, where it sends a request to the server computer. The server then acknowledges the request and sends the experiment page’s source, which is then received by the browser (the client) and displays the page on the participant’s

computer. Data can be sent back and forth between client and server, and any data collected such as audio transcript and answers to questionnaires can be collected on the server side. Each webpage can present formatted texts, images, animation and links to other services as well as media such as audio and videos (Birnbaum, 2004) as needed for different components of the experiment workflow. Participants progress through the webpages through button access from one webpage to the next according to the designed experiment workflow.

2.3 Previous Work on Web-Based Online Experiment

The use of the web as delivery platform is not a new concept, as there has been significant effort to develop methodologies and techniques, tools and recommendations in designing and delivering experiments on the web. This section presents existing knowledge of web-based experiment methodology. Specifically, it presents knowledge gained in conducting experiments on the web, common online experimental issues, and understanding of advantages and drawbacks of online experiment methodology.

2.3.1 Conducting Experiments on the Web

A wealth of knowledge has been gained over the last 20 years in terms of conducting experiments on the web. This can be shown from two aspects: 1) technical knowledge in delivering an experiment on the web, and 2) methodologies of conducting an experiment online, including classic experimental design, and delivering different types of experiments on the web.

With respect to the first aspect, basic technical knowledge for creating the basic web applications has been well-established. This include programming techniques such as HTML and client-server programming, web server hosting. Knowledge in the use of online audio and video players and data-logging has also been well-established as basic requirements for a web-based experiment (Anderhub, Müller, & Schmidt, 2001; Reips, 2002a; Birnbaum, 2004). Section 2.2 also briefly presented technical knowledge such as client-server interaction and how participants interact with the experiment webpages on the web.

For the second aspect, it is known that classical design considerations including within-subject, between-subject, factorial, quasi-experiment factors designs can be implemented on web-based experiments, just like in a traditional lab experiments (McGraw, Tew, & Williams, 2000; Reips, 2000;

Reips, 2002a). These can be implemented during the design of the web applications through designing for participants' progression through the required structure of web pages and what variables and stimuli to use. As well, one can also use existing webpage-generating tools such as WEXTOR and WebExp that take into account these design criteria (Reips & Neuhaus, 2002; WebExp Development Team, 2004).

In terms of delivering different types of experiments online, different methodologies have been proposed. For example, for surveys and interviews studies, techniques include using web-based surveys integrated with dynamic data management and verification systems for better real-time data analysis (Cooper et al., 2006). Here, online survey webpage-generating wizards such as SurveyWiz, and cloud-based online survey services such as SurveyMonkey® have been offering researchers the capability to realize this technique to deliver survey-based studies on the web (Birnbaum, 2000; Andrews et al., 2003; Marra & Bogue, 2006).

For interviews, the use of text-, audio, or video-based online chat services (MSN, Skype, etc) can be utilize to record and produce transcription history automatically (Gruber, Szmigin, Reppel, & Voss, 2008). These chat services also enable researchers to conduct such interviews on the web conveniently without having to travel to participants' location or vice versa.

Simulator-type experiments can be performed using virtual laboratories (i.e. physics and chemistry models) for e-learning purposes. Examples include Ko et al. (2001) creating a web-based virtual laboratory tailored to frequency modulation experiments; client browsers could show an instruments GUI, and a lab PC connected to a physical apparatus through LabVIEW. As well, Albano, Iovane, Salerno, & Viglione (2005) proposed a web-based simulator structure for virtual scientific experiments and e-learning that included web browsers and a server interfacing with a simulation model editor, visualization tool, and course management software.

2.3.2 Advantages and Drawbacks

Several researchers have examined the advantages and drawbacks of web-based verses traditional laboratory research, with the general consensus that the advantages of online-experiment methodology outweigh its disadvantages. Table 2-1 presents some of the reported advantages and disadvantages.

Table 2-1: Advantages and drawbacks of online experiments methodology

Advantages	Drawbacks
<ul style="list-style-type: none"> • Ease of obtaining large, diverse sample size contributing to high statistical power and generalizability of findings from high external validity (Reips, 2000; Birnbaum, 2004). • Ease of access to very rare “SMEs” (Birnbaum, 2004). • Avoidance of organizational problems with schedule and travel (Reips, 2002a). • Cost saving of lab space, equipment, man-power, time constraint (Reips, 2000; Granello & Wheaton, 2004; J. Byrne, Heavey, & P. Byrne, 2010) • Reduction of experimenter effects and thus demand characteristics (Hewson, Laurent, & Vogel, 1996). • Choice of completely voluntary, anonymous participation for sensitive topics (Reips & Krantz, 2010). • Automatic data verification, access to raw data, statistical analysis and filtering (Andrews et al., 2003; Rademacher & Lippke, 2007). 	<ul style="list-style-type: none"> • Risks of participant misunderstanding instructions / project information with absence of physical presence of lab assistant (Kraut, Olson, Bruckman, Cohen, & Couper, 2003; Ollesch et al., 2006). • High dropouts if no incentives given (Senior et al., 1999). • Threat of uncontrollable internet downtime / network outage causing delays (Reips, 2000; Greiner, 2002). • Participants’ computer anxiety risks associated with complexity of technology leading to bias results (Reips & Krants, 2010). • Change of online environment from physical lab environment may influence data collection in certain scenarios (Anderhub et al., 2001). • Internet security risks and possible multiple submissions (Hewson et al., 1996; McGraw et al., 2000; Anderhub et al., 2001; Byrne et al., 2010).

2.3.3 Common Online Experiment Issues

The literature also discusses several common online experiment issues as well as techniques proposed to deal with them. These common online experiment issues include dropouts, double participation, subject recruitment, incentives, and security.

Dropouts refer to participants who quit the study before completing it (Birnbaum, 2004). Researchers are recommended to build trust and credibility through providing full disclosure of the

study intent, clearly-defined tasks, access to researchers, and even a third-party guarantor (i.e. ethics research office) (Andrews et al., 2003). Also researchers should place a demographics questionnaire in the beginning of the study instead of at the end to prevent unexpected surprises to participants (Andrews et al., 2003; Reips, 2002b). This can also serve as to force participants who may just be curious about the study, or simply not committed to drop out early, leaving only seriously committed participants to continue (Reips, 2002b; Birnbaum, 2004). Warm-up techniques such as adding a task before actual experimental manipulation can also achieve similar result as above in reducing dropout rates, as well as ensuring that the dropout did not happen due to experimental manipulation (Senior, Phillips, Barnes, & David, 1999; Reips & Krantz, 2010).

Double participation refers to participants who repeatedly participate in the same experiment (Greiner, 2002). Common techniques for controlling this include assigning a unique ID for each participant and associated payment information (Greiner, 2002), as well as creating an off-line site for very interested participants to continue participating without adding to data collection and thus double participation (Birnbaum, 2004). However, researchers still need to accept the limitation that it is still difficult to control the decision-making process of participants to double-participate, as well as understanding the trade-offs between maximum participant control verses maximum sampling points (Greiner, 2002).

Another very common issue during online experiments in terms of subject-recruitment is to recruit for a more balanced or larger subject sample size. To achieve more representative samples, one can provide multiple accesses to the same study from different online locations on the World Wide Web (Reips & Krantz, 2010). As well, a popular technique is to turn to crowd-sourcing to recruit participants for online experiments, such as running experiments on Amazon Mechanical Turks, an online crowd-sourcing place for labour-intensive tasks (Paolacci & Stern, 2010). The advantages of this technique include very fast recruitment (workers being paid), subject diversity and low cost, such as \$1.40 / hr labour fee. However, concerns can include: 1) not obtaining a true representation of online population, 2) avoiding penalizing participants who choose to withdraw, and 3) a complete lack of environmental control, such as workers cooking while participating in the experiment (Paolacci & Stern, 2010; Mason & Suri, 2012; Crump, McDonnell, & Gureckis, 2013).

A common question raised since the introduction of online experiment methodology has been the validity of data collected online compared to that collected in a physical laboratory environment.

A vast majority of findings from past researchers have strongly pointed to equally-valid data compared to physical laboratory environments (Krantz, Ballard, & Scher, 1997; Anderhub et al., 2001; Ollesch, Heineken, & Schulte, 2006). However, caution should still be taken to carefully evaluate the nature of the test environment, as not all cases will result into equally-valid data between online versus physical environment. A specific example of a scenario where, participants may be affected by online environment to be more risk-seeking than in a classroom environment for experiments on lottery evaluation (Shavit, Sonsino, & Benzion, 2002).

Finally, one very common issue that researchers need to face when delivering experiments on the web is security. Fortunately, there have been a wealth of and continuously-evolving knowledge and techniques in improving website security. Example techniques can include maintaining access control by username and password, communication encryption, use of secure HTTP protocols, to name a few (Cooper et al., 2006; Microsoft, 2015).

2.4 Assessment of Potential for Existing Web Platforms to Deliver Complex Research

Studies on the Web

This section analyses existing web platforms that have been used by researchers to deliver an experiment on the web as of 2015. The purpose was to understand whether existing web platforms were adequate for delivering complex research studies on the web. As a review, an ideal web platform must meet all the capability requirements of a complex research studies simultaneously and fully to successfully deliver such studies online. The analysis is presented in Section 2.4.1. Implications drawn from the analysis are presented in Section 2.4.2.

2.4.1 Analysis on Existing Web Platforms

This section presents the analysis on existing web platforms. A review was conducted on existing papers that involved delivering an experiment on the web to look for the types of web platform used to deliver the experiment on the web, as well as papers that proposed web experiment methodology with mention of these web platforms. Studies involved in these papers ranged from psychology, science, economics, education, music to aviation. Specifically, in the interest of this thesis, the literature review looked for studies that involved delivering aviation simulator-based

experiments on the web. The result is not an exhaustive list of tools in detail, but rather to provide readers an idea of the range and capabilities of existing tools being used to date.

The analysis consisted of assigning existing web platforms into different categories and rating each category against the capability requirements for delivering complex research studies as discussed in Chapter 1. The requirements are summarized here again as: 1) designed for multi-participants interactions, which may include interaction with an experimenter as well, 2) designed for complex task environments such as a simulator environment requiring collaboration and professional skills, 3) designed to integrate with standard experiment procedures such as briefing, consent and scheduling, 4) high degree of research controls over participant performance (i.e. progress monitoring and performance mentoring), participant selection (i.e. login control, participant qualification and scheduling), as well as data collection process (i.e. specify what data to collect and when).

Web-based remote laboratory: Web platforms in this category consist of web browsers providing graphical interface for simulation software such as Simulink running on a physical computer or on physical laboratory equipment. They can provide a single-participant interaction or a collaborative workspace for experiment involving scientific simulation modelling, virtual biology labs, virtual chromatography exercise, and collaborative e-learning (Schoenfeld-Tacher, McConnell, & Graham, 2001; Shin, Yoon, K. Lee, & E. Lee, 2002; Chaturvedi, Akan, Bawab, Abdel-Salam, & Venkataramana, 2003; Holbert & Albu, 2003; Dori, Barak, & Adir, 2003; Albano et al., 2005; Gillet, Nguyen Ngoc, & Rekik, 2005; Stone, 2007; Jensen, 2009). An example can be accessed in the link here: <https://sites.google.com/a/cord.edu/labview-for-analytical-chemistry/> (Jensen, 2009).

Web platforms in this category fully meet requirements #1 and #2 as they have provision for online multi-participant interaction remotely through online conferencing, and remote lab environments needing collaboration and special skills. However, requirement #3 cannot be met due to lacking in provision to integrate other experiment procedures with complex task environment with a dedicated role of interfacing with simulation software / physical equipment remotely. For example, the aforementioned link to the “LabVIEW for Analytical Chemistry” experiment web platform provide access to chemical experiment simulations interfacing with LabVIEW. However, experiment components such as scheduling, questionnaire, and consent form are not included as part of the platform function (Jensen, 2009). Finally, requirement #4 can only be met partially through

provision for instructor's control over data collection parameters and login for authorized personnel, but not participant selection.

Stand-alone web pages with embedded image files / animation applet: Web platforms in this category consist of HTML web pages containing simple questionnaire, embedded image files, Flash / Java applet, or media players for animation, auditory or game interaction-type experiments (Welch & Krantz, 1996; Senior et al., 1999; Brand, 2004; Metzger & Bridges, 2004; Ollesch et al., 2006; Charness, Haruvy, & Sonsino, 2007; Kelly, 2015; Shultz, 2015). Current webpage-generating tools such as WEXTOR, WebExp, Ensemble, and ROEM generate webpages belonging to this web platform (Reips & Neuhaus, 2002; WebExp Development Team, 2004; Tomic & Janata, 2007; Hills, 2008).

None of the four requirements can be met by web platforms in this category, due to its delivery of single-participant, anonymous web experiments to general public from the studies as referenced above. There is simply no implementation for multi-participant interaction, complex task environment or research control.

Web-based "shared-workspace" platforms: Web platforms in this category consist of a web application specifically for online collaboration between two or more people on a shared workspace. The workspace can be used for simulation, document creation, and conferencing tasks. It can be done either synchronously, such as multiple participants connected at the same time, or asynchronously such as a participant leaving a message behind for other participants for further work. Examples include BSCW, AlephWeb, Manicoral and CoVitesse (Fürst, Haagmans, Naeije, & Nielsen, 1997; Laurillau & Nigay, 2002; Korichi & Belattar, 2008).

Requirements #1, and 2 can be met fully with the ability to provide online collaboration remotely through online conferencing and interaction, as well as provision for collaborative simulation tasks. However, achieving requirement #3 would currently require integrating existing platforms with other simulation tools. An example would be the combination of Basic Support for Cooperative Work (BSCW)¹, NetMeeting², and Arena Simulation Software³ (Korichi & Belattar, 2008). Requirement #4 can only be met partially through provision for instructor's control over data

¹ <http://www.bscw.de/english/features.html>

² <http://www.microsoft.com/en-ca/download/details.aspx?id=23745>

³ <https://www.arenasimulation.com/>

collection parameters and login for authorized personnel, but without participant qualification and scheduling capability.

Dynamic web-based surveys: Web platforms in this category can be seen as dedicated web-based questionnaires with capabilities such as real-time database management, questionnaire modification, and statistical analysis. An example of this type of survey system includes third-party online survey services such as SurveyMonkey® (Reips, 2002b; Kraut et al., 2003; Cooper et al., 2006; Gruber et al., 2008; Kohavi, Longbotham, Sommerfield, & Henne, 2009; Tsai, Egelman, Cranor, & Acquisti, 2011; Cantrell et al., 2013; O'Brien et al., 2014; Hsu & McFall, 2015). Due to the dedicated role as web-based questionnaire, none of the four requirements can be met by the web platforms.

Web-based crowd-sourcing services: Web platforms in this category consist of online services that enlist the services of larger online community for experiments, such as Amazon's Mechanical Turk (Paolacci & Stern, 2010; Cooke, Barker, Lecumberri, & Wasilewski, 2011; Mason & Suri, 2012; Crump et al., 2013; Hamm, 2014).

Here, none of the requirements can be met by these web platforms fully. For example, there is no multi-participant interaction online for a given task due to anonymity of the "workers" as single participant participating in a given task at any given moment. As such, there is very little research control as well. Finally, while the majority of tasks administered to participants have been simple tasks requiring few minutes to finish (Paolacci & Stern, 2010; Hamm, 2014), there are emerging platforms seeking to address this issue. Examples include CrowdForge⁴ and Turkomatic that petitions complex tasks into collaborated, smaller tasks (Kittur, Smus, Khamkar, & Kraut, 2011, Kulkarni, Can, & Hartmann, 2012). Thus, requirement #2 may be met at least partially with these emerging platforms.

Interactive web-based simulation applications: Web platforms in this category are dedicated web-based simulators. Studies delivered through the web platforms can include various interactive simulation studies on engineering modelling, engineering process operation, neural-network simulation and ATC simulators (Luo, Chen, Yücesan, & Lee, 2001; Hamza-Lup et al., 2009; Guravage, 2011; Link, 2015; Ross, 2014).

⁴ <https://github.com/borismus/CrowdForge>

Requirements # 1 and 2 can be met fully through providing multi-participant interaction such as with the Sky-High ATC simulator (Link, 2011), as well as complex simulation environments requiring professional skill and collaboration. However, requirements #3 and 4 cannot be met due the inability to incorporate other experiment processes and lack of research controls implementation due to dedicated web-based simulator role.

2.4.2 Implications

As mentioned in Chapter 1 introduction, from the above analysis, there is a clear limitation to the current existing web platforms in fully meeting all four requirements simultaneously. This can be clearly seen with Table 2-2 below (“✓” met fully, “~”met partially, “✗” not met). As a result, in relation to delivering complex research studies on the web, the message is clear that a new type of web platform technology is needed to meet the four requirements simultaneously in order to successfully deliver a complex research study on the web.

Table 2-2: Summary of web platform category ratings against the four requirements of delivering a complex research study

Web Platform Category	REQUIREMENTS			
	1. Multi-Participant Interaction	2. Complex Task Environment	3. Integrate Experiment Procedures	4. High Research Control
Web-based remote laboratory	✓	✓	✗	~
Stand-alone web pages with embedded image files / animation applet	✗	✗	✗	✗
Web-based “shared workspace” platforms	✓	✓	✗	~
Dynamic web-based surveys	✗	✗	✗	✗
Web-based crowd-sourcing services	✗	~	✗	✗
Interactive web-based simulation applications	✓	✓	✗	✗

2.5 Existing ATC-Flight Simulators

As the thesis uses an interactive ATC-flight simulation research study as a representative complex research study on the web, this section briefly reviews examples of existing ATC-flight simulators. From the literature review and online search using the term “interactive flight-ATC simulators”, the author observed a lacking of web-based ATC-flight simulators. However, other non-web-based flight-ATC simulators were identified, including VATSIM, PilotEdge, Multi-Aircraft Control Systems (MACS) by the National Aeronautical and Space Administration (NASA), and ATC-flight trainers by ATC Flight Simulator Co.

For example, VATSIM and PilotEdge are internet-based, professional online simulation network. They allow pilots and controllers to connect their flight simulators such as Microsoft Flight Simulator FSX and X-Plane to a virtual world. VATSIM has attracted professional aviation bodies, such as MITRE, to use it for new arrival procedure evaluations (VATSIM, 2015; MITRE, 2009). PilotEdge has been used for training by Arizona State University’s aviation programs for pilots to talk to real-live professional controller all in simulation network (Thurber, 2015).

In terms of non-internet-based simulators, the MACS and ATC-flight trainers from ATC Flight Simulator Co. offers mid-fidelity, human-in-the-loop air traffic simulation to multiple participants to be included in one simulation (Prevot, 2002, ATC Flight Simulator Company, 2015). MACS particularly offer rapid-prototyping user interface for air traffic control as well as flight management systems on the flight deck. Examples of research studies done with MACS included Vu et al. (2013)’s study looking at influences of UAS pilot communication and execution delay on controller’s acceptability ratings on the pilot response while UAS operates in National Airspace. As for ATC Flight Simulator Co., products such as ATC610 and ATC710 offer both professional pilots and controllers dedicated physical cockpit / ATC simulator stations, approved by the Federal Aviation Administration (ATC Flight Simulator Company, 2015).

2.6 Chapter Summary

This chapter introduces to the reader an overview of the concept of web-based experiments, as well as a presentation of previous works on web-based experiments. Existing best knowledge was presented in terms of ways of conducting online experiments, dealing with common research issues, advantages and drawbacks of experiments on the web, and common types of online experiments

being delivered. As well, examples of web-based flight-ATC simulator research studies being delivered on the web as of 2015 were presented.

While there has been a significant amount of knowledge gleaned from the past on internet research methodologies, limitations to current web platforms still exist, contributing to a lacking of more complex research studies, such as a flight-ATC simulator research study being delivered on the web. Clearly, there is an opportunity to address the limitations with existing web-platforms. This is discussed in detail in the next few chapters in terms of the creation of Integrated Modular Platform, its evaluation and lesson-learned results. As well, there has been a lacking of web-based ATC-flight simulator studies, but existing non-web-based ATC-flight simulators are available.

Chapter 3

The Integrated Modular Platform

To respond to the need for a new web platform technology to deliver complex research studies, a prototype of such a platform was created. The “Integrated Modular Platform” was designed to address the limitations of existing web platforms to deliver complex research studies. The creation of this platform fulfils Objective 1 and 2 of this thesis, as outlined in Chapter 1.

This chapter first presents the methodology for creating the platform. A set of design objectives are established (Section 3.1) and then used to develop a “Platform Model” of a coding structure that would meet those objectives (Section 3.2). Finally, the Platform Model was implemented in code to create the prototype Integrated Modular Platform (Section 3.3).

In developing the Integrated Modular Platform a distinction is drawn between the term “researcher” and “experimenter”. A researcher refers to the creator and owner of a study, while an experimenter refers to someone taking the role of a “research assistant” position to help run the experiment as a moderator only.

3.1 Design Objectives for the Platform

Three design objectives for the Integrated Modular Platform were identified based on the goals set out in Thesis Objective 1. The first design objective was to support the experiment workflows required to deliver an interactive ATC-flight simulator study. Such a study, as representative of a complex research study on the web, would allow critical functionalities and corresponding technologies to be identified.

The second design objective was to develop a recruitment process that would attract professional controllers and pilots as SMEs for the study. This design objective would be realized by adding additional workflow components for the recruitment need, such as screening and scheduling.

Finally, the third design objective was to develop a platform with high reusability and extensibility for different types of studies, without the need for a researcher to modify computer programming codes or re-build the platform from scratch. By meeting this objective, future researchers, especially non-programmers, would be able to use this platform for different types of

studies, despite having limited or no programming skills. This would allow the platform to support other complex simulator studies, potentially including survey-type or interview-type studies on the web.

3.2 Development of the Platform Model

Having identified three design objectives, a visual representation, the “Platform Model” was developed of the overall structure and individual components of a prototype web platform. The steps of development involved: 1) identifying a representative experiment workflow of a complex research study being delivered on the web (Section 3.2.1) and 2) using a distributed systems architecture to form the Platform Model in order to realize the identified experiment workflow (Section 3.2.2).

3.2.1 Identifying a Representative Experiment Workflow of a Complex Research Study

An experiment workflow refers to the sequence of experiment activities from start to finish. For example, a simple experiment might consist of recruiting participants, obtaining consent, running a single a trial and collecting data. A more complex experiment workflow might include recruitment, briefing, consent, multiple trials, and a post-experiment questionnaire. In order to develop a representative workflow for online experiment delivery, the workflow from a complex, laboratory, study on information asynchrony was chosen as a reference workflow (Yuan & Histon, 2014). This workflow is presented in Figure 3-1.

In the figure, participants were recruited participants from various sources (i.e. advertisement emails, personal contacts, or signs/posters), and asked to schedule a study session at the lab. On the day of the study, the experimenter would welcome the participant help him or her to settle down in the lab (participant reception activities). The participant would then be presented Component 4 and 5. If the participant consents to participating in the study, then the participant would go through data collection tasks from Component 6 to 9. Participants would typically be looping through “Simulator Trials” and “Post-Trial Questionnaire” until all the trials have been completed, before proceeding on to post-experiment questionnaire. After the post-experiment questionnaire, participants would be debriefed including a post-study summary.

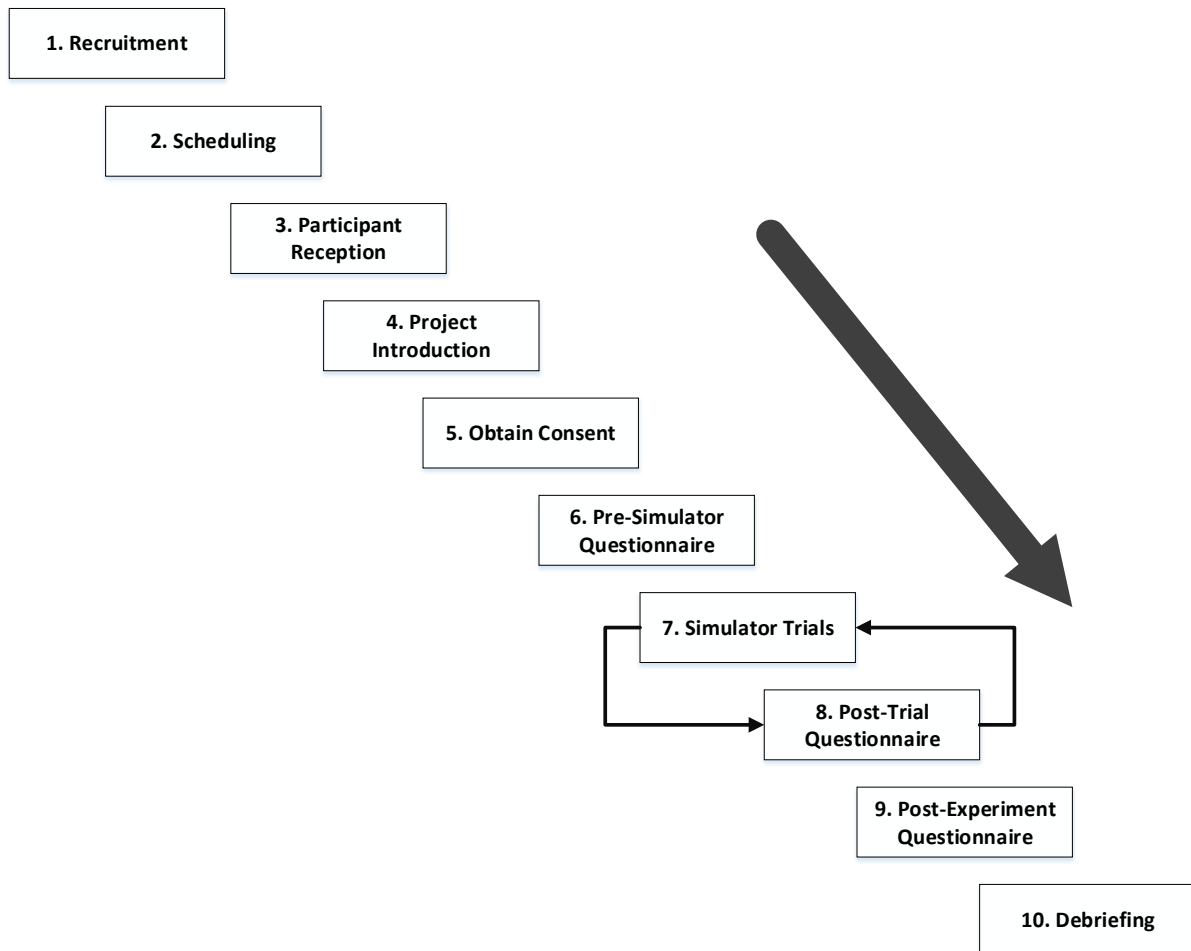


Figure 3-1: Reference workflow

However, the reference study just described was delivered in a traditional laboratory environment, using non-expert students as participants. In order to take into account the web environment, and recruitment needs for SMEs instead of non-expert participants, the reference workflow above was modified to address four concerns. The revised experiment workflow is presented in Figure 3-2 below. Components highlighted in grey with solid border line (added) and dashed border line (sequence switch) have been changed from Figure 3-1.

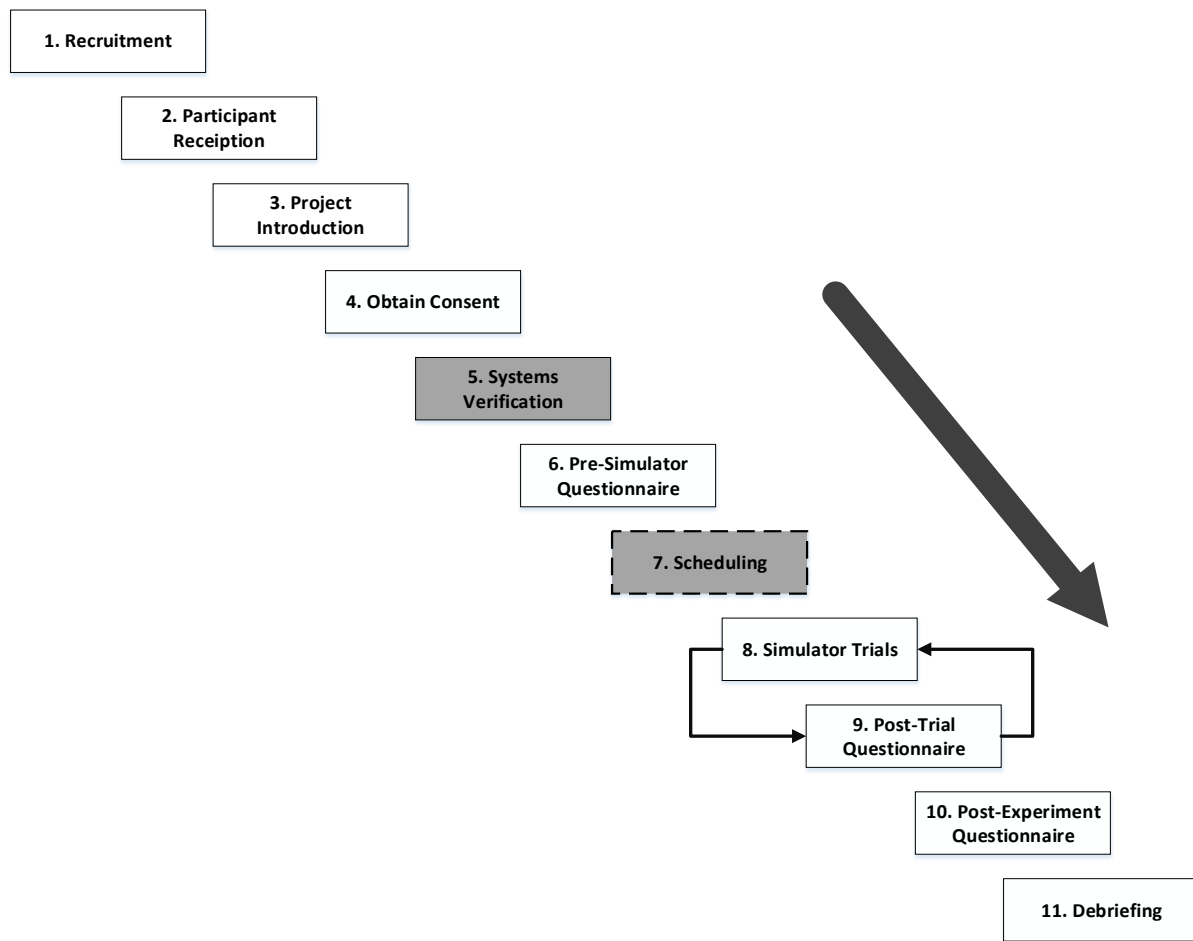


Figure 3-2: Experiment workflow for web delivery of a complex research study

First, in an online environment, the recruited participants would arrive from recruitment emails at the experiment website, and be oriented on what to do and what the website is about. This can be achieved by “Participant Reception” workflow component by a landing web page on the experiment website.

Second, as the study would be delivered on the web, researchers would have to rely on participants’ systems to be compatible to the technologies to be used to display the webpages. Thus, an additional workflow component is needed to check participants’ system technical compatibility. This component would have to reject potential participants who did not meet the technical requirements. Preferably this should be right before a pre-simulator questionnaire, as there would be no point of having a potential participant participate in the questionnaire if he or she would be rejected for not meeting the simulator requirement.

Third, with online delivery, there is the potential of participants either not consenting to the study or being rejected due to not meeting system requirements. To avoid complications with scheduling unqualified/non-participating individuals, it would be helpful if the scheduling component was moved to right before the simulator trials, after the self-served system verification and pre-simulator questionnaire.

Finally, with the potential of recruiting SMEs, researchers would need to screen SMEs to ensure professional background qualified. One way of doing this can be done through asking potential participants for their professional backgrounds using the pre-simulator questionnaire, then verifying the response later, before confirming participants' scheduled dates. The pre-simulator questionnaire component was deemed sufficient for this purpose.

3.2.2 A “Platform Model”

Having established the experiment workflow, the next step was developing a model of an online experiment delivery platform. The “Platform Model” is a visualization of a design for delivering the representative experiment workflow online while also being highly reusable for different research studies, and usable by researchers with little to no coding experience.

A distributed system design concept was adopted to achieve the above needs and was labelled the Integrated Modular Platform. The design concept called for a collection of different components in the form of platform modules; together the modules would form a single cohesive system allowing a researcher to create a customized study. These modules would be integrated together within a web application, contains the programming codes that create webpages (“experiment webpages”) that deliver a complex research study experiment workflow on the internet.

A platform module is defined as a set of pre-created and specifically-designed web page templates, potentially containing one or more existing online technologies, used to realize one or more workflow components. Researchers would have the ability to pick and choose, among a list of modules available to him or her, the desired modules to formulate a specific experiment workflow. The experiment workflow would be formulated by configuring the modules through a user-friendly interface to generate and link desired experiment web pages together. These experiment web pages realize the individual workflow component, and through the links, the overall experiment workflow.

The experiment web pages are linked through a set of dynamically configured “previous page” and “next page” buttons on each web page.

For clarification, the term “experiment web pages” here refers to the web pages of a web-based experiment itself. Participants would interact with these experiment web pages after having been generated by the experiment modules. For example, a “document delivery” module can be used to be a project introduction page or post-questionnaire page, which the participants would interact with from their web browsers.

In addition to generating experiment web pages, some modules may also generate “experimenter-only web pages”. These web pages are only accessible for the experimenter to interact with. This is solely for the purpose of research control or data management such as login accounts. For clarity, only a researcher who seeks to create and deliver a study on the web would directly interact with the modules, using them as templates to generate and link desired experiment web pages together. Participants would only interact with the generated experiment web pages, and an experimenter with any generated experimenter-only web page.

The module approach allows the platform to take advantage of external third-party services, reducing or eliminating the need for coding by an experimenter. Modules can include HTML embed code in the webpage template to integrate appropriate third-party services, or customized logic for more advanced coders. The “HTML embed code” here refers to a short line of HTML codes provided by a third-party online service, such as SurveyMonkey®, for developers to use on their web applications (SurveyMonkey®, 2015). By integrating external third-party services, a researcher can directly use all the functionalities that the service provides without having to code them, or rely on participant ‘switching.’ As third-party services are continuously updated by third-party developers, this would provide a high level of extensibility for the platform itself in terms of emerging technologies to meet future experiment-delivery needs. As well, the power of using an embed HTML code would also allow participants to choose between third-party services providing the same general functionality, depending on preference or specific research needs.

Finally, the Platform Model includes a user-friendly interface to configure the modules to generate and link experiment web pages. This is referred to in this thesis as the “Workflow Configuration User Interface”. This would avoid the need for a researcher to dig into the code for

modification. It is important to note that this interface is not a module itself, but a web page, much like a “setting” page of an online blog.

3.2.3 Illustrating the Platform Model

In order to illustrate more fully how modules are related to an experiment workflow, Figure 3-3 shows a notional experimental workflow. To illustrate the flexibility of the module approach, some of the modules are shown using built-in custom-made technologies, while others were embedded with third-party technology.

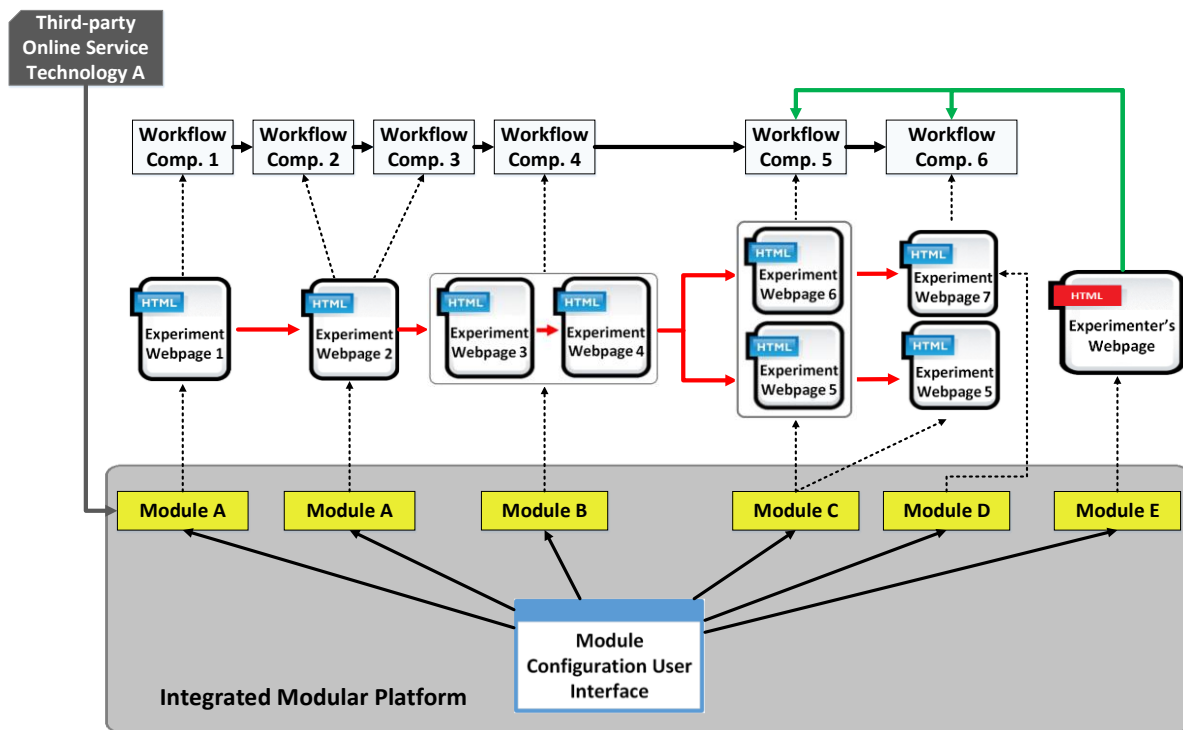


Figure 3-3: Resulting platform model for implementation

Here, each module in the figure captures six different utilization cases to realize workflow components in terms of variations in generated experiment webpages, and number of utilizations of modules. Each case is described in sequence in the figure from left to right.

Module A (first from left) – Single workflow realized by single webpage: A module may consist of a single-webpage template that realizes one workflow component. Note that this is the

simplest case, where the module is utilized once to generate a webpage to realize a workflow component.

Module A (second from left) – Multiple workflow realized by single webpage: A module may consist of a single-webpage template, utilized once, to generate a single webpage, but realizing multiple workflow components. An example would be where a “Project Introduction” and “Obtaining Consent” workflow components be realized by one single webpage, delivering a combined project introduction + consent form document. Notice that this case also demonstrate that one single module can be utilized multiple times to realize multiple workflow components (i.e. workflow component 1, 2, and 3).

Module B – Webpages in sequence: A module may consist of a template to generate two or more webpages in sequence. This is where a participant must go through the web pages in sequence generated by that particular module, in order to fulfill a workflow component (e.g. workflow component 4), or multiple workflow components (not shown).

Module C – Webpages in parallel from a single module: A single module may consist of a template to generate two or more webpages that will be accessed together in parallel (i.e. two separate browser tabs opened). An example of parallel web-pages would be the “Online Conference Module” generating an online conference setup page, which would open a chat window on another web browser as a separate web page.

Module C & D – Webpages in parallel from multiple modules: There can be a case where multiple modules each deliver a single web page in parallel (i.e. simultaneously run) to fulfill a single workflow component. For example, the chat window web page from Module C may be needed in conjunction with other web pages (i.e. video-only simulator web page generated by “Simulator Delivery Module” or post-trial questionnaire web page generated by “Document Delivery Module”) in order to be continuously in communication with the experimenter and other participants. This would fulfill either the “Simulator Trials” or the “Post-Trial Questionnaire” workflow component, respectively (see Figure 3-2). This is represented in the figure as “Webpage 5” as the chat window web page and “Webpage” 7 as the video simulator or post-trial questionnaire web page.

Module E – Experimenter-only webpage: Some modules may not generate experiment webpages (for the participant), but are dedicated to providing the experimenter a web page for

overall experiment control purposes, such as participant progression through certain workflow components. This is shown in Module E. Note that some modules may also generate an experiment webpage and an experimenter-only webpage for management purpose of a particular functionality. An example include a login experiment webpage for participants, and a login-management web page for the experimenter to manage login accounts.

3.3 Implementation of Platform Model

The implementation of the Platform Model involved creating the actual Integrated Modular Platform. Section 3.3.1.1 first describes how researchers would use the Integrated Modular Platform conceptually, and the current implementation of the Platform’s web-based application. Then, Section 3.3.2 presents the details of the implemented modules with discussions on each module’s utilization, configuration options, and presentation of some example screenshots.

3.3.1 Use of the Integrated Modular Platform

3.3.1.1 Envisioned Utilization of the Integrated Modular Platform

To illustrate how the Integrated Modular Platform would be used, Figure 3-4 to Figure 3-6 show how the Workflow Configuration User Interface would be used to create an experiment on the web. These figures were for illustration purposes only, and is not meant to be final appearance of the user interface. It was envisioned that the interface would be implemented in the form of a set of web pages on the internet, similar to the “customization” page for online blogs, for users to create a personal blog. As a start, the researcher would first access the user interface and click on the green button to start a new workflow. This is shown in Figure 3-4.

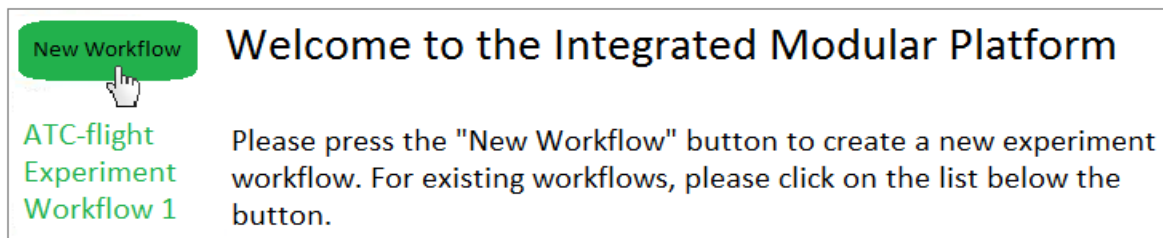


Figure 3-4: Workflow Configuration User Interface impression – create new workflow

Next, the researcher would be prompted to select the modules that he or she would need to realize the experiment workflow. A notional example is presented in Figure 3-5, showing the module

selection interface. A researcher would select modules in the order he or she would like the experiment webpages to be generated and linked together to realize the desired experiment workflow.

ATC-flight Experiment Workflow 3

Please formulate your workflow by choosing the desired modules to the list from the "Choose Module" drop down menu. Linking of the modules are automatically done. Please click on each row in the list to configure the module for desired page.

Choose Modules		#	Module	Description	To prev page	To next page	Technology	
Document Delivery	<input type="checkbox"/>	1	Navigation	This is for welcoming page	-	YES	N/A	Delete
Navigation	<input type="checkbox"/>	2	Document Delivery	This is for project introduction	YES	YES	FluidSurvey	Configure
System Verification	<input type="checkbox"/>	3	Document Delivery					Configure
Scheduling	<input type="checkbox"/>		Add a module					
Online Communication	<input type="checkbox"/>		Add a module					
Simulator Delivery	<input type="checkbox"/>		Add a module					
...	<input type="button" value="Add more row"/>							

[Deploy!](#)

Figure 3-5: Workflow Configuration User Interface impression – choose modules to formulate workflow

In addition, Figure 3-5 also shows the standard features that come with individual modules used for generating participants’ experiment web pages only, including 1) a set of HTML page-link buttons (“To prev page”, “To next page”), and 2) integrated module technology (“Technology”). The “page-link” buttons refer to a set of HTML “next page” and “previous page” buttons. Participants would click on these buttons to proceed to the next or previous experiment web page. The “integrated module technology” refers to pre-chosen technology options integrated with the module itself. As mentioned, this include embedded third-party online services for their technology, or a custom-built technology built-in into the module.

For example the second row shows a “Document Delivery” module configured to generate experiment webpages to realize the “Project Document” workflow component. This module has been configured to use both the “next page” and “previous page” buttons, as indicated under the “To prev page” and “To next page” column. FluidSurveys™ was specified to be the technology of choice.

The actual configuration of the above aspects are done in individual configuration interface for each module, as shown in Figure 3-6. This interface is accessed by clicking on any of the blue “Configure” buttons, as shown in Figure 3-5.

Document Delivery Module

Provide a brief description of the page this module represents:

This page is for study consent.

Page Appearance

Title

Sub-Title 1

[Add more elements](#)

Technology Choice

Third-Party Embed Codes

[Use default](#)

Page Link Logic

Previous Page Button

Next Page Button

[More advanced logic](#)

Figure 3-6: Workflow Configuration User Interface impression – configuring a module

Here, the researcher is modifying the features on a “Document Delivery Module” to create an experiment web page for consent form. One can see the titles being added, as well as the HTML embed code for a third-party technology to be integrated into the module code. However, a technical limitation would exist where a researcher can embed the wrong third-party technology into a module, such as FluidSurveys™ in an “Online Communication” module. This is possible since each module is essentially a web-page template that can take any HTML embed code to embed any application that would generate such code. Thus, researchers would need to adhere to the rule that one should only choose different brands of the same type of third-party online services specific for a module type. As well, the Workflow Configuration User Interface should include algorithms to prevent a researcher to use a wrong type of technology for a given module.

The “Page Link Logic” section allows researchers to specify which of the two (or both) page-link buttons should be on the experiment web page. By default, the algorithm in the Workflow Configuration User Interface would automatically link the buttons to the last and the first experiment web page generated by the previous and next module in the order as shown in Figure 3-5, respectively. However, researchers can provide specific link address to any web pages if desired. Finally, the “More advanced logic” link provides researchers the option for abilities such as to enable and disable buttons during simulator session to provide participant progress control to the experimenter.

The configuration options shown in Figure 3-6 apply to all modules used for generating participants’ experiment webpages, unless otherwise specified. After the researcher has finished configuring all the modules, he or she would return to Figure 3-5 to press the deploy button. This would create the online experiment for delivery to participants on the web.

3.3.1.2 Current Implementation

3.3.1.2.1 Approach

There were two major implementation parts to the Integrated Modular Platform: 1) the platform modules, and 2) the Workflow Configuration User Interface. As previously defined, a platform module is a set of pre-created and specifically-designed web pages that serve as templates to generate experiment web pages. In a technical sense, these are HTML web pages serving as templates to become experiment web pages. Thus, platform modules in plural form can be seen as a collection of sets of HTML web page templates to deliver different experiment web pages in order to realize multiple experiment workflow components on the web.

In order for the modules to exist, the HTML web page templates must be hand-created by the author first, along with the Workflow Configuration User Interface, resulting in a code package that realizes the Integrated Modular Platform. This then provides repeatability, where future researchers can then take the code package, host them on the web through a web server such as Windows Internet Information Services (IIS)⁵, then use the modules to create desired experiment web pages through the Workflow Configuration User Interface.

⁵ Windows IIS website: <https://www.iis.net/>

Unfortunately, due to time constraint, the Workflow Configuration User Interface was not implemented in the current prototype of the Integrated Modular Platform. Thus, the current prototype of the Integrated Modular Platform consisted of only the platform module being created. Any customization to the modules needed to create experiment web pages (mimicking Figure 3-6) currently needs to be done by hand-coding.

3.3.1.2.2 Creating the Modules

The author hand-created each individual module, using ASP.net on Visual Studio 2012, through first creating the codes to form generic HTML web page. An example code is as below:

```
<%@ Page Language="C#" AutoEventWireup="true" CodeBehind="WebForm1.aspx.cs"
    Inherits="IDEA.WebForm1" %>

<!DOCTYPE html>
<html xmlns="http://www.w3.org/1999/xhtml">
<head runat="server">
    <title></title>
</head>
<body>
    <form id="form1" runat="server">
        <div>
        </div>
    </form>
</body>
</html>
```

Figure 3-7: Codes for generic HTML web page

Additional features were then appropriately added to transform the generate HTML web pages to become webpage templates. The addition included basic page appearance elements such as colour and title. HTML buttons codes were also included as appropriate as part of the standard features, such as in Figure 3-8:

```
<asp:Button ID="ToSSSButton" runat="server" class="fwdarrow" style="float: right" Text="To Simulator
Session Scheduling" Width="325px" Height="35"
PostBackUrl="~/InfoAsynchStudy_SimSessionSchedule_Page.aspx" />
```

Figure 3-8: Codes for HTML buttons

Finally, either HTML embed codes generated from a third-party service (Figure 3-9), or functions for custom-made technologies written in JavaScript, specific for each module. Appendix L shows the complete code sample for the “Document Delivery Module”.

```

<script type="text/javascript" src="//fluidsurveys.com/media/static/embed-
helper.js">{"url":"//fluidsurveys.com/api/v3/embeds/"}</script><div class="fs-embed" data-
token="eyJ1c2VyIjoyMTI3Mjc4NDY4LCJpZC16MjQ4MH0.8vg_rvu0008npDJ_hAn65gkxs8A"><div
class="footer">powered by <a
href="http://fluidsurveys.com/?utm_source=fluidsurveys&utm_campaign=powered-
by&utm_medium=embeds" target="_blank"><span
class="highlight">FluidSurveys</span></a></div></div>

```

Figure 3-9: HTML embed codes generated from a third party service

Once all the modules were created, the codes were then hosted on the web through a server machine using ISS at <http://rbhagat.uwaterloo.ca/IDEA> (Lien, 2015). A screenshot of the code package being hosted on the web by ISS is shown in Appendix M.

As a technical note, in order to realize the envision utilization as described in Section 3.3.1.1, future work would require major modification to the current module code structures would be needed in order to provide the ability to dynamically change features as in Figure 3-6. Current structure does not allow this flexibility as many of the features were hard-coded into the code structure.

3.3.2 Module Demonstration

This section presents eight modules that were created as part of the Integrated Modular Platform. The following subsections present the modules including (as appropriate) discussion on: 1) module utilization, 2) its template form (default form before configuration), 3) configuration options, including alternative potential third-party technologies, and 4) example screenshots of the implemented module. Any third-party-services used by the modules were identified through the Google search engine.

The eight modules are presented in three categories. Section 3.3.2.1 presents modules designed to generate experiment web pages for participants only. Section 3.3.2.2 presents modules designed to generate experiment web pages for participant interaction alongside an experimenter-only web page for managing the interaction. Section 3.3.2.3 presents modules designed to provide experimenter-only web page for research control purposes.

3.3.2.1 Modules for Generating Experiment Web Pages for Participants

3.3.2.1.1 Navigation Module

This module was designed for transitioning between different workflow components. It does not fulfill any specific workflow components. Thus, in a technical sense, it is more or less a single generic HTML web page that allows researchers to add HTML buttons features and other page elements. The main usage of this module is to create experiment webpages for participants to seamless transition from one workflow component to another. An example would be creating a “Welcome Page” for participants to “land” on from recruitment email, or a “waiting page” for participants to wait while the experimenter sets up next trial. Furthermore, this module generates one single experiment web page per use. To generate multiple transitioning web pages, researchers need to use this module multiple times. Finally, while it is possible to embed a third-party technology into this module in light of the limitation as discussed in Section 3.3.1.1, researchers are discouraged to do so in order to preserve the distinction between the purposes of different types of modules.

3.3.2.1.2 Document Delivery Module

This module is designed to deliver project documents, questionnaires and surveys on the web and generates one single experiment web page to deliver a document per use. By default, the integrated module technology is provided by the embedded third-party online survey service FluidSurveys™⁶ to fulfill delivering both pure documents and questionnaires on the web. To specify what documents to be delivered through this module, researchers would first create the documents on FluidSurveys™ itself. A unique embedded HTML code would be generated for different documents, as shown in Figure 3-10⁷. Assume that the Workflow Configuration User Interface is implemented, a researcher simply copy-paste the unique embedded HTML code to the appropriate configuration section in the interface, as shown in Figure 3-6, to deliver the specific document on the experiment web page generated by this module. The technical detail of how the copy-paste HTML codes into module code from the Workflow Configuration User Interface would still need to be researched as future work. Without the Workflow Configuration User Interface, current

⁶ <http://fluidsurveys.com/>

⁷ The iFrame code is essentially the same as Embed code, but allows the designer to specify height and length of the questionnaire window within the code itself appearing on the experiment web page.

implementation requires the HTML embed code to be hard-coded by hand into the module code to create the experiment web page through Visual Studio 2012.

Sharing Options Allow respondent to share content with social media sites

Access Restrictions [View Restrictions](#)

Site Restrictions
Only allow submissions from these sites (wildcards accepted). This is a comma-separated list.

Web URL

Embed Code Iframe Code Insert this code into your website page in the position you would like the survey to appear. Preview

```
<script type="text/javascript" src="//fluidsurveys.com/media/static/embed-helper.js">{"url":"//fluidsurveys.com/api/v3/embeds/"}</script><div class="fs-embed" data-token="eyJ1c2VyIjoyMTI3Mjc4NDY4LClpZCI6MjQ4MH0.8vg_rvu0008npDJ_hAn65gkxs8A"><div class="footer">powered by <a href="http://fluidsurveys.com/?utm_source=fluidsurveys&utm_campaign=powered-by&utm_medium=embeds" target="_blank"><span class="highlight">FluidSurveys</span></a></div></div>
```

Figure 3-10: HTML embed codes generated by FluidSurvey

Three criteria were identified for choosing third-party online survey services other than FluidSurveys™: 1) be embeddable onto a web page with HTML embed codes, 2) data privacy, and 3) ability to deliver documents and questionnaires alike. The first criterion is a “must-have” criterion, as the module is designed specifically for a third-party online service for its technology. The second criterion points to a data-privacy concern with professional participants in light of the US Patriot Act, where the US government has the authority to pry into collected data of US-based online surveys with data storage location within the American continent (Loh, 2011). This was one of the reasons that the author chose FluidSurveys™, which maintains its data storage in a Canadian location. This would hopefully minimize the risk of professional participants rejecting to participate in the study due to concerns of US government agencies accessing recorded conversation or performance, and thus jeopardizing their careers. While not a “must-have” criterion, it is a legitimate concern to take into consideration. The third criterion points to the need for the third-party service to have templates to deliver both pure documents and questionnaires like with FluidSurveys™. This is also another “must-have” criterion in order for this module to fulfil its purpose properly.

Alternative options to FluidSurveys™ include SurveyMonkey®⁸ and SurveyGizmos®⁹. These two online third-party services meet the first criterion, and is expected to meet the third as well from its feature descriptions (SurveyMonkey, 2015; SurveyGizmos, 2015). However, these are US-based third-party online services¹⁰, thus do not meet the second criterion.

An example screenshot of the document delivery module generating a demographic questionnaire experiment web page is shown in Figure 3-11. Default integrated module technology was used.

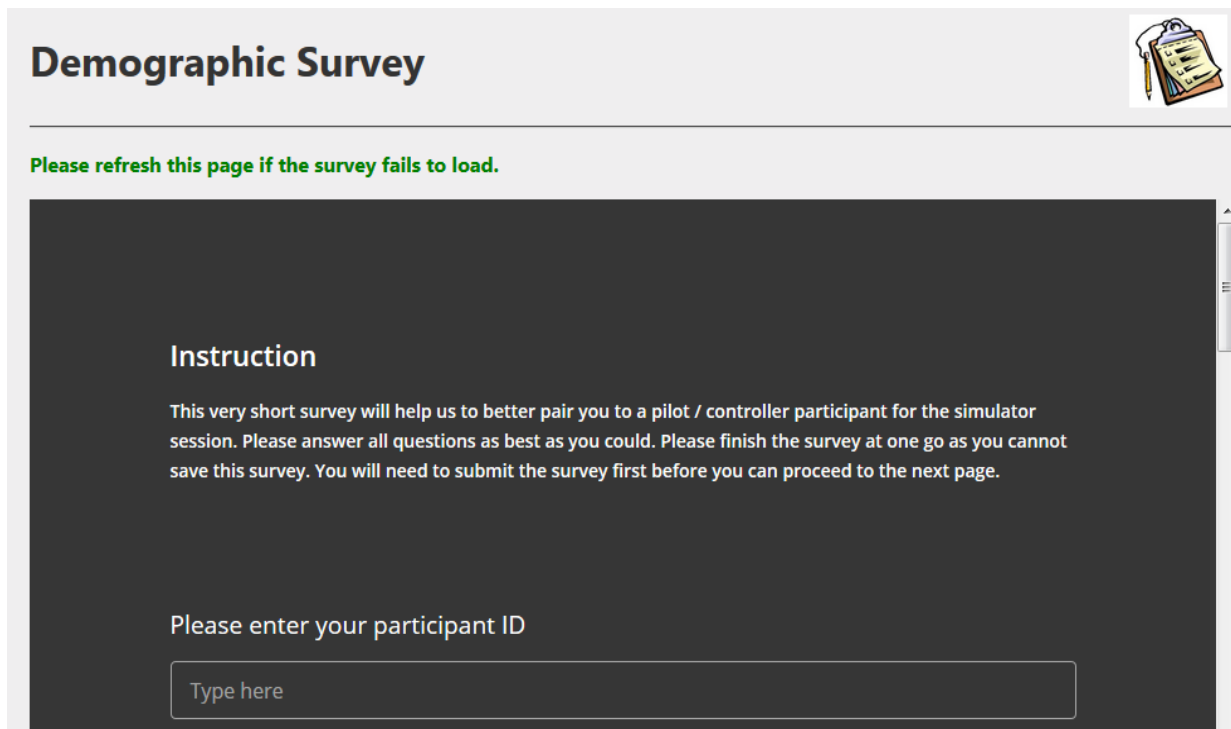


Figure 3-11: Document delivery module configured as a demographic questionnaire page

3.3.2.1.3 Scheduling Module

The scheduling module was designed to deliver self-served online scheduling capability. The experiment webpage generated by this module would allow participants to indicate available dates

⁸ <https://www.surveymonkey.com/>

⁹ <https://www.surveygizmo.com/>

¹⁰ FluidSurvey™ merged with SurveyMonkey® as of August 2014, but still retained its data storage location within Canada as of 2015 (Deren, 2014).

for a study session as part of the experiment workflow. Furthermore, this module generates one single experiment web page for participant scheduling.

By default, the integrated module technology is provided by the embedded third-party scheduling service SuperSAAS¹¹ by default for its scheduling calendar technology. Different calendar template on SuperSAAS can be used to suit different scheduling needs. Two criteria for choosing online third-party scheduling services were identified: 1) embeddable onto a web page with HTML embed codes, and 2) high customizability.

The first criterion is a must-have as explained earlier. The second criterion points to maximizing the module's potential with high customizability through different calendar configurations for different scheduling needs. While not a "must-have" criterion, it is highly recommended (i.e. the reason for choosing SuperSAAS as it excels in meeting this criterion). Alternative options to SuperSAAS meeting the two criteria include Full Slate¹² and Acuity Scheduling^{TM13} with different templates for reoccurring appointment, double booking, and individual or group event signup (Inuit.inc, 2015; Acuity Scheduling, 2015).

An example of an online schedule web page is shown in Figure 3-12. SuperSAAS was used in the module to generate the web page as shown. This example showed a two-slot registration on the calendar for a pilot and controller participants in the case of an ATC-flight simulator study.

¹¹ <http://www.supersaas.com/>

¹² <http://www.fullslate.com/>

¹³ <https://acuityscheduling.com/>

Simulator Session Scheduling



Scheduling Instructions

1. Scroll down this page to the main (large) scheduling calendar.
2. Click on an empty slot (0/1) of your respective role. 3. Click "New Participation".
4. Enter your participation number.
5. Click "Create Participation".
6. Scroll to the bottom of this page and click "Complete Registration" button to complete the scheduling process.

Please refresh this page if the scheduler fails to load.

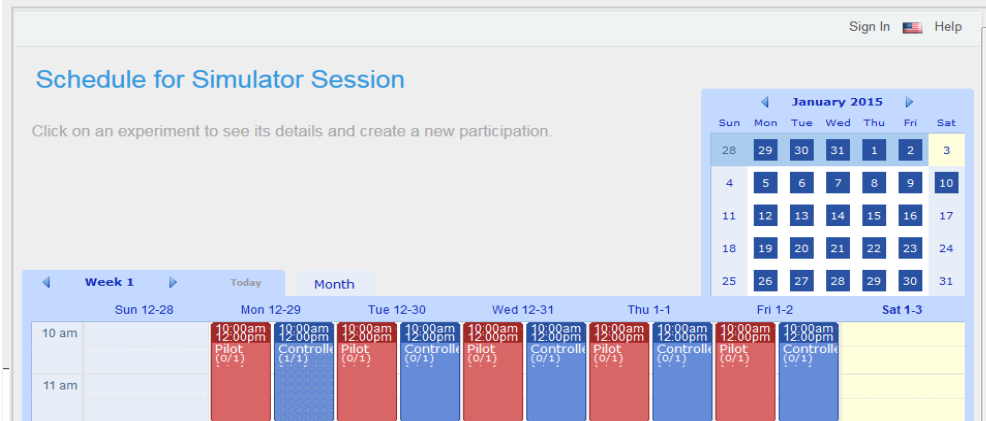


Figure 3-12: A scheduling module configured for ATC-flight simulator study need with double slot

3.3.2.1.4 Online Communication Setup Module

This module was created for online conferencing verbally between multiple participants and the experimenter. Specifically, the module generates an experiment web page for participants to set up an online conference with each other and with the experimenter. This involved the experiment web page automatically opening a chat window in a separate web browser during setup process.

By default, the integrated module technology is provided by the embedded third-party online conference service Google Hangout¹⁴. Two criteria were identified for choosing third-party online conference services: 1) be embeddable onto a web page with HTML embed codes, and 2) unified login process with no dependency on browser and OS version. The first criterion was previously explained. The second criterion refers to a login process where participants do not need to download different versions of third-party service software depending on browser or OS version on personal computer / desktop for better user experience. This was a criterion that led to the choosing of Google Hangout

¹⁴ <https://plus.google.com/hangouts?hl=en-GB>

over Skype¹⁵, as both met the first criterion. For example, different external Skype software has to be downloaded for Windows 7 (Skype Desktop) and Windows 8 (Skype App). However, Google Hangout is web-based, with the sign-in process much like signing into Gmail. This enabled Google Hangout to be compatible for both Windows and Mac OS, and browser versions including Internet Explorer, Firefox and Google Chrome. The second criterion is not mandatory, but highly recommended for user experience consideration.

3.3.2.1.5 System Verification Module

The system verification module was created to fulfil the system verification workflow component. The module was designed to automatically check for compatibility of participants' computer systems to the requirements for a simulator session. As well, the module would act as a gate to prevent participants from proceeding further in the workflow (e.g. to schedule a simulator session) if the requirements are not met.

Thus, the integrated module technology consists of a custom-made built-in technology with three test functions¹⁶ for: 1) operation system (OS) version, 2) browser version, and 3) network stability requirements. The first two tests were identified since different versions with the operating system (i.e. Windows, Mac) and client browser were envisioned as factors that can affect online simulator delivery technology. The tests for OS and browser version check against the OS and browser currently used by the participants' computer. Participants must be using compatible versions required by the online simulator study in order to pass the test. Researchers can configure for different OS / browser test parameters. The network stability test was identified since instability can affect time sensitive variables for some experiments. The test was implemented to obtain a network latency value every two seconds for six seconds. The value was a ping value sent from the host server in author's lab to the client network and back. One must obtain three values that are less than the allowable threshold (configurable as well) in order to pass the test (i.e. < 500 milliseconds). As a note, for less time sensitive studies, this network latency suggestion test may not be necessary.

¹⁵ <http://www.skype.com/en/>

¹⁶ JavaScript was used by the author to develop the codes for the three test functions.

A built-in algorithm was included in the module in order to enforce the restriction that participants must pass all the tests on the modules in order to proceed to the next page. This was done through keeping the “next page” button disabled unless the tests were passed.

Currently there is no provision for choose alternative technology in this module. However, provision for such can be added in the future with emerging technologies. An example screenshot of the experiment web page generated by the system verification module is shown in Figure 3-13. Notice how the “next page” button linked to the pre-experiment questionnaire web page (demographic survey) is kept disabled unless the participant passes all three test cases.

System Requirement Check

[Instructions](#)

Please follow the three steps below to check whether your system meets the online simulator system requirements. You must pass all the check items in order to proceed with the rest of the study.

1. Click on the "Equipment Check" button to make sure you are using Windows OS.
2. Click on the "Network Latency Check" button to verify your average network latency is below 500 ms. If the test fails (getting at least one ping test result that is above 500ms), click on the button again. You may do this several times.
3. Scroll to the bottom of the page. If you passed all the check items, click on the activated "To Demographic Survey" button to proceed with the rest of the study.

NOTE # 1: If you see the test failed the majority of times after several tries, we suggest that you **do not participate** in this study as the online simulator may not work properly.

NOTE # 2: You must use **Google Chrome** and **Windows PC** for the simulator session. Otherwise the online simulator will fail to work. Please make sure you have those available before proceeding.

Equipment Check

Operating System: unchecked

Network Latency Check

Network latency at 0 seconds: unchecked

Network latency at 3 seconds: unchecked

Network latency at 6 seconds: unchecked

[← Back to Consent Information](#) [To Demographic Survey](#)

Figure 3-13: System verification page

3.3.2.1.6 Simulator Delivery Module

The simulator delivery module is designed specifically to deliver any simulator video and audio output to a participant's web browser. The module provides researchers the ability to create multiple "simulator rooms" for participants of different roles to perform in. Each "simulator room" receives its own video and audio feed provided by the simulator. For example, a pilot in an ATC-flight simulator study would see a navigation display feed, while the controller would see an ATC radar feed. The feed can both be a static feed (e.g. a picture) or dynamic feed (e.g. a video). As such, this module generates an experiment web page showing the room list and the simulator video feed. Furthermore, as only the simulator video feed is being delivered on the web, the experimenter would need to physically manipulate the inputs to the simulator while sitting in the lab in response to participants' responses to the video feed.

The integrated module technology consists of a custom-made web Real-Time Communication (webRTC) technology¹⁷ built into the module. The technology is responsible for delivering the simulator video-feed from a PC desktop screen to the web browser. The video feed is streamed¹⁸ on the web using virtual webcam software such as ManyCam¹⁹ on the physical simulator computer (Visicom Media.Inc, 2015). As a technical note, currently, the Integrated Modular Platform can only stream .webM format due to the webRTC specification (Muaz-Khan, 2015). Virtual webcam software has already taken this into account, thus researchers do not need to worry about file format when using the Integrated Modular Platform along with virtual webcam software.

Researchers should download the software separately as this would not come with the platform package. The choice of webRTC was due to its latency-management that was tested to be much better than other alternatives such as Justin.TV (Justin.TV, 2015), with as much as a 4-second difference. The choice of alternative technology is currently not applicable for this module due to the specialized setup. Figure 3-14 shows the generated "room list" web page showing two virtual simulator rooms.

¹⁷ Source code by Muaz-Khan (2013).

¹⁸ Continuously streaming using the desktop-capturing function.

¹⁹ <https://manycam.com/>

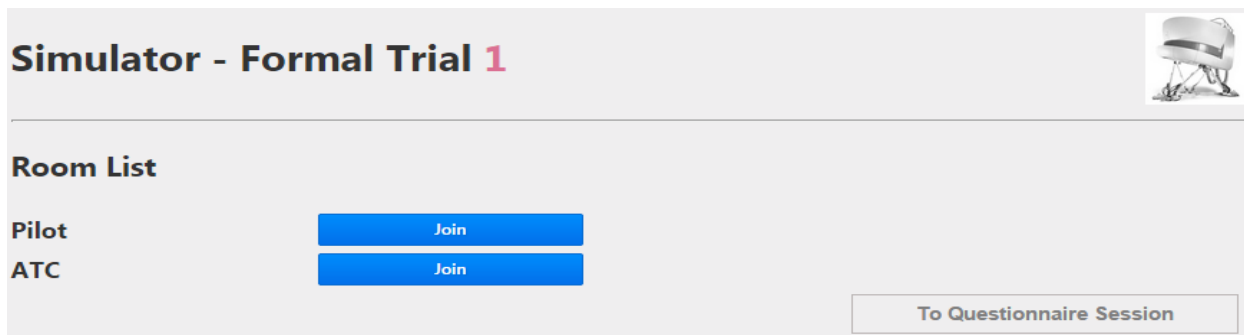


Figure 3-14: The “room list” experiment webpage

3.3.2.2 Modules Providing an Experimenter-only Web Page in addition to Participants’ Experiment Web Pages.

3.3.2.2.1 Login Management Module

The login management module manages online logins for role assignment and security purposes. This module does not fulfill a specific workflow component, but rather for security of the overall experiment. The module generates a participant’s login web page, and a login account management page for the experimenter only. Both webpages are connected to a backend database²⁰ storing unique user IDs and passwords of authorized participants. An experimenter can create and delete user ID and password information on this module (note this would mean that experimenter would provide pre-created ID and password information to authorized participants only). As well, the experimenter can gain access to any of the “experimenter-only” web pages from this web page.

This module is simply designed to have a set appearance features and interface for participant login and account management for experimenters. There are no page-link buttons available in this module, and configuration option is not applicable to this module.

3.3.2.3 Modules for Generating Experimenter-only Web Page.

3.3.2.3.1 Experimenter’s Session Control Module

This module provide experimenter’s control over participant progress, online data collection, simulator room setup, and setup online conference on the experimenter’s side. The module generates an experimenter-only web page solely to provide research control over the simulator session. This

²⁰ The database was part of the ASP.net code package. No external database setup such as MySQL would be needed.

included controlling participants' progress control and online data collection process. Progress control is achieved through applying the advanced link logic to enable / disable page link buttons to applicable modules to generate experiment webpages. As for data collection, different data collection functions can be controlled through specify which data to collect and when to turn on / off. In addition, experimenter would set up virtual simulator rooms on this web page, as well as opening up a chat window for conference with participants.

Modification to the default features is currently not applicable in this module, as the data collection functionality were built-in and specialized as demonstration. However, provisions would be made in the future to allow third-party data collection technologies to be embedded.

Figure 3-15 shows the experimenter-only web page with its features. The top row presents the simulator room setup function, as well as online conference setup button for Google Hangout. Box "1" represents the "next trial number" button control²¹. Box "2" represents the button control to start / stop data collection features. Box "3" and "5" present button control for enabling and disabling "next page" and "previous page" buttons for participants' progress control. In this case, the buttons were configured to controls workflow loop between next simulator trial and post-trial questionnaire. The "finish simulation" button breaks off that loop. Box 4 presents the audio recording function for data collection, and finally the boxes in the middle of the module presents the latency measurement recording function.

²¹ This function should have been part of the "simulator room creation" function and is automated. However, the author did not have time to implement the automation, thus made this function manual.

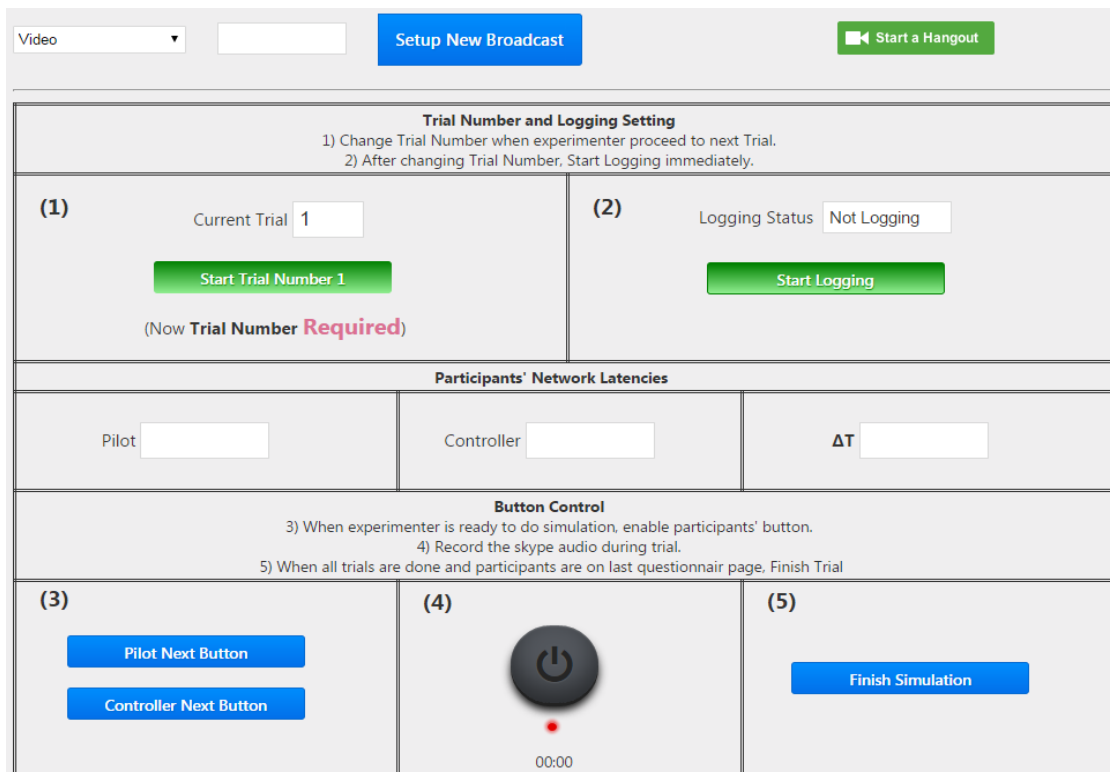


Figure 3-15: Experimenter’s session control module

3.4 Analysis of Integrated Modular Platform as Designed

This section presents four topics examining how the implemented platform design handles several experiment design considerations. The first topic looked at the challenge of integrate data collection across multiple third party services (Section 3.4.1). The second topic examined how the Integrated Modular Platform supports different data collection needs (Section 3.4.2). The third topic of interest was how the Integrated Modular Platform was designed for acceptability by SMEs during recruitment (Section 3.4.3). Finally, the fourth topic looked into ease of utilization of the Integrated Modular Platform by a non-programmer researcher to set up an experiment (Section 3.4.4).

3.4.1 Integrating Data Collection across Multiple Third-Party Services

An immediate issue that may be encountered when using the Integrated Modular Platform is the challenge of integrating data collection results from multiple third-party sources. Particularly, the issue lies in correlating data collection results to individual participant to keep track and preserve anonymity. In a physical lab, this issue can be solved through using unique and anonymous

participant ID (i.e. “P001”), to keep track of the data collection results such as consent form and questionnaires. For example, participants would be asked, under the monitor of the experimenter, to write down the participant ID on the questionnaire papers.

In the case of the Integrated Modular Platform, data are collected through independent third party services; tracking date/time is not thought to be sufficiently robust for correlating a single participant’s responses across the services. The solution of using a unique participant ID can also be used on online studies using the Integrated Modular Platform. However, there are two problems to overcome in terms of 1) providing a participant ID to each participant, and 2) having that participant ID be recognized and used by the third part services. This is particularly challenging when some of the steps are performed by participants during pre-simulation data collection, without the presence of an experimenter facilitating the process, as in a physical lab.

A fully automated solution would have participant IDs generated and assigned to each user and automatically passed on to each third-party service. However, there are not standard interfaces for accepting a unique identifier with all services, and requiring such an interface would severely limit the ability to take advantage of those services. Consequently, an alternative approach was developed. The first problem was overcome by using a random ID generator (i.e. generating a unique 4-character string for participants ID) embedded in one of the generated webpages. Participants would record the generated ID (such as on the consent form page) for subsequent usage for the rest of the study if he or she agrees to the consent conditions to participate in the study.

As for the second problem, it was straightforward to add a single input box on questionnaires and forms delivered by third-party online surveys and have participants input their participant ID directly. However, there is the risk of participants losing their ID prior to simulator session, forgetting to input ID, or making typography error during input. Researchers can enforce through experiment webpage design that participants must complete necessary pre-simulator data collection in one go. This would prevent the risk of participants losing the ID if they were to return to finish up the pre-simulator data collection; it can also mitigate the risk with participants forgetting to input ID in some documents, or making typographical errors in the input. For example, experimenter can intelligently verify and correct through particular date and time on third-party online services such as FluidSurveys™ that the submitted documents belong to a particular participant.

3.4.2 Support of Different Study Needs

The third design objective in Section 3.1 stated the need for a platform that is extensible to different study needs. This is assessed by looking at several examples that point to the capabilities and limitations of the implemented Integrated Modular Platform.

In terms of capabilities of the Integrated Modular Platform, studies that require data collections through surveys and interviews can be achieved. For example, the “Document Delivery” module can allow surveys to be delivered, while the “Online Communication Setup” module can allow participants and experimenter to conduct interviews on the web. Recordings of the transcripts can be achieved through the embedded recorder on the web page generated by “Experimenter’s Simulator Session Control” module. As well, the “Simulator Delivery” module can allow simulator-based tasks requiring participant-experimenter interaction in combination of the above data collection methodologies to be accomplished. Anonymous, self-served studies requiring stimuli such as images and Flash animation can also be met through uploading the stimuli on third-party online services such as FluidSurveys™, along with other project documents (O’Dacre, 2012).

However, there are certain data collection needs that cannot be met by the Integrated Modular Platform due to two limitations in the design. First major limitation is the lack of a control interface between the web browser and the physical PC. Thus, any study requiring participants’ direct control of the simulator would not be possible unless such interface is incorporated into the “Simulator Delivery” module. Example studies requiring direct control of the simulator may include telemetry or cockpit environment simulation where the current voice-command implementation would be too slow for response time to changing situation.

Second limitation is the inability to for the Integrated Modular Platform to provide for certain data collection process within a trial, where the researcher would like to collect data during trial run. Examples of this include SAGAT stop (Jacko, Yi, Sainfort, & McClellan, 2012) in situational awareness studies, where simulation is randomly paused to administer a questionnaire. This inability is due to the design nature of separate “Document Delivery” and “Simulator Delivery” modules generating separate webpages, where participants need to press the “next page” button to proceed from a simulator webpage to a document webpage. However, this limitation may be overcome by advanced algorithm for future development of the Integrated Modular Platform. The algorithm should be incorporated in the aforementioned two modules to generate webpages that can allow automatic and

random transition between simulator and questionnaire. For example, participant can be automatically brought to the questionnaire page from the simulator page while the simulator on the physical computer is automatically paused as well. The simulator would then automatically resume from the pause when participants return to the simulator page after submitting the questionnaire.

3.4.3 Design Contribution to Acceptability of SME Recruitment

With the possibility of using this Integrated Modular Platform for studies with SMEs as stated in the second design objective, how the design contributes to the acceptability of recruitment of SMEs was examined.

The module design of the Integrated Modular Platform makes it very easy to create consistent webpage presentations, producing a more professional and credible presentation for recruitment. For example, researchers can use different types of technologies in different module configurations to meet different participant population's expectations of professionalism. One group may find Skype to be much more professional for online communication usage than Google Hangout, while the other group may not. The template feature from the platform modules can thus allow researchers to choose a particular "module configuration options" that has certain professionalism standard already incorporated while creating different complex research studies. Future development of the Integrated Modular Platform should incorporate an algorithm that can save different module configurations as "configuration options" for researchers to re-use. Currently, researchers would have to note down the options manually on paper.

3.4.4 Ease of Utilization by a Non-Programming Researcher

Finally, the design objectives for the Integrated Modular Platform stated that it should be usable by researchers without modifying code. The module design eliminates much of the need for deep programming as the necessary technologies to realize workflow components are already incorporated in each module by default. Furthermore, the proposed Workflow Configuration User Interface would be very helpful in further eliminating the need to modify codes through providing user-friendly interface to configure the modules. For example, researchers can simply drag-and-drop selected modules and typing in titles or other required appearance features of the web page to be generated.

However, further development to the Workflow Configuration User Interface is still needed in order to fully eliminate the need for researchers to deal with HTML codes. This is due to the current proposed interface requiring researchers to copy and paste HTML embed code for third-party online services in the text box. The author suggests providing a drop-down list of available third-party online services for applicable modules that researchers can select. This would require further research in technical feasibility of such a proposal.

3.5 Chapter Summary

This chapter described the design process of creating the Integrated Modular Platform through first defining the platform capabilities. Then, a Platform Model was defined through using the experiment workflow of a laboratory study on information asynchrony by Yuan & Histon (2014) as a reference workflow. As the original study was done in a physical lab with university students as non-expert participants, web environment and SME recruitment considerations were incorporated to create a new experiment workflow representative of a complex research study to be delivered on the web. A “distributed system” design approach was utilized to formulate the Platform Model. This called for platform modules to be created in order to incorporate existing technologies and meet high reusability need for different studies. Researchers choose and configure a set of modules through a user interface to generate and link desired experiment web pages together. These experiment web pages realize the individual workflow component, and the link realizes the experiment workflow.

The design of the implemented Integrated Modular Platform was also assessed with respect to experiment design issues that may be encountered. The strength of the design in terms of modules and incorporation of third-party technologies allowed high flexibility to meet different study needs, such as studies requiring surveys, interview, or simulator components. However, studies requiring direct participants’ control of the simulator cannot be realized due to the lack of direct control interface between browser and physical simulator PC. Another strength of the Integrated Modular Platform is its template ability to generate web pages while maintaining a set of experiment design and professional standards for consistency. This can be very helpful for SME recruitment.

With the platform implemented, the next step was to evaluate this platform through a case study approach. A follow-up study on information asynchrony was selected to be the case study to be delivered on the web using the implemented platform. This is discussed in Chapter 4.

Chapter 4

Design of a Case Study Evaluation of the Integrated Modular Platform

In order to evaluate the Integrated Modular Platform proposed in Chapter 3, a case study approach was used. A follow-up, online study, of an information asynchrony study, originally delivered in a physical lab (Yuan & Histon, 2014), was developed as a representative ATC-flight simulator study that could be delivered using the Integrated Modular Platform. This chapter presents the experiment used in the case study. The evaluation of the performance of the Integrated Modular Platform for delivering the case study is presented in Chapter 6.

This chapter is organized as follows. Section 4.1 presents the motivation and background for the follow-up study. Section 4.2 presents the experiment design of the follow-up study. Finally, Section 4.3 describes how the Integrated Modular Platform was used to realize the experiment design and deliver the follow-up study on the web.

For clarification, the term “researcher” used in this chapter strictly refers to the person who creates the experiment. The term “experimenter” refers to the person who conducts the experiment only. A “research assistant” refers to a person helping the “researcher” in various tasks, such as data analysis or help run the study as an “experimenter”.

4.1 Background on Information Asynchrony

Information asynchrony is a term associated with the distribution of information to multiple parties such as weather, flight charts, traffic information and non-cooperative objects such as UAS and bird flocks. A key challenge is when there are asymmetric time delays associated with the distribution of any surveillance data from a common source to a pilot and controller. This was termed information asynchrony (see Figure 1-1). A recent safety alert from the National Transport Safety Board (NTSB) highlighted the challenges pilots have in comparing out-the-window views of weather to graphic depictions of weather derived from radar. The Next-Generation Radar (NEXRAD) weather data may be as much as 20 minutes older than an age indication on displays in cockpit, and pilots may be confused reconciling what they see out the window with their graphical weather display (National Transportation Safety Board, 2012).

An emerging area of concerns is the distribution of surveillance data on Unmanned Aerial Systems (UAS). UAS refers to a “separate system that is required to support air operation without pilots on board the aircraft” (Federal Aviation Administration, 2013). There has been a recent steady increase of civil application of such systems in civilian airspace for applications including, but not limited to, security surveillance, disaster response and aerial photography. Smaller UAS may have limited-to-non-existent surveillance and communication capability, and thus act more like a non-cooperative object in line with weather and bird-flocks.

A better understanding of the limits of information asynchrony is important for guiding the development of new technologies, procedures and operational governing the distribution of surveillance data about UAS to both pilots and controllers. For example, UAS data may be passed to a System Wide Information management (SWIM) architecture from ground-based radar surveillance, then to pilots and controller, but through different system paths (Yuan et al., 2013). Each system may have a different latency due to hardware, software, human operations and cognitive complexity in information processing (Yuan & Histon, 2014). Consequently, pilots and controllers may have different situation awareness due to the presence of information asynchrony and this would be expected to affect their communications (Yuan & Histon, 2014).

Understanding the conditions (e.g. amount of time delay) that trigger the effects of information asynchrony is important for the design of future surveillance distribution systems affecting integration of UAS into controlled airspace. In addition, the understanding will have the potential to help mitigate current information discrepancy problems as well, such as with the aforementioned weather data age discrepancy with the NEXTRAD weather imagery.

4.1.1 Previous Work on Information Asynchrony

There has been a great amount of work in the past on the effect of delays in a control loop on operator performance. Latency in feedback can have detrimental effects performance such as increased errors and movement time in tasks involving target acquisition and telemanipulation of objects (Currie & Rochlies, 2004; Lum et al., 2009). This is also true in collaboration tasks, where latency caused increased time to completion, and over and undershoot errors over targets during multiple robot manipulator control tasks, as well as collaboration breakdowns in a jigsaw-puzzle task (Allison, Zacher, Wang, & Shu, 2004; Gergle, Kraut, & Fussell, 2006).

In aviation, numerous studies have also looked into data asynchrony topics and found common degradation effects on pilot-ATC performance, causing conflicts and inappropriate interactions. For example, Nadler, Mengert, Disario, Sussman, & Grossberg (2009) found increasing transmission delays on ATC communications can affect transfer of critical information with increase number of simultaneous transmissions between pilots and controllers. Similarly, Mosier et al. (2013) also found that information conflicts (i.e. failure to pass along or receive most up-to-date information) was found in over half of a set of 128 Aviation Safety Reporting System (ASRS) reports involving incidents such as near-midair collisions filed between June 2000 and January 2003.

A common theme with all the above studies (except Mosier et al., 2013) was that the research focus had been on a time delay in a feedback loop. However, there has been a lack of research done to date, specifically looking at the human factor challenges in terms of two or more parties receiving the same information from the same source at different times. The aforementioned study by Mosier et al. (2013) only looked into identifying the cause of such information conflict, such as different weather information seen on ATC ground radar and ATC radar (Mosier, 2013).

4.1.2 Previous Preliminary Study on Information Asynchrony

Yuan & Histon (2014) conducted a preliminary study on information asynchrony, in order to determine how unequal time delays in the distribution of non-cooperative surveillance data can affect pilot-controller communication. The experiment recruited 24 university students as participants. Participants were paired into a pilot-controller group to participate in the experiment. A static navigation display and ATC radar display were presented to the pilot and controller participant, respectively. A divider was placed between the two participants as shown in Figure 4-1. The displays showed weather, normal airline traffic, UAS and bird flocks as surveillance data. Information asynchrony was only applied to non-cooperative data such as UAS and bird flocks. Time delay values of 0, 0.5, 1, 5 and 10 minutes were used. One participant received up-to-date information (e.g. no time delay) while the other participant received data with the time delay value applied to it. Participants communicated with each other according to the traffic situation presented on the static displays to resolve an impending collision situation, with UAS in the presence of information asynchrony.

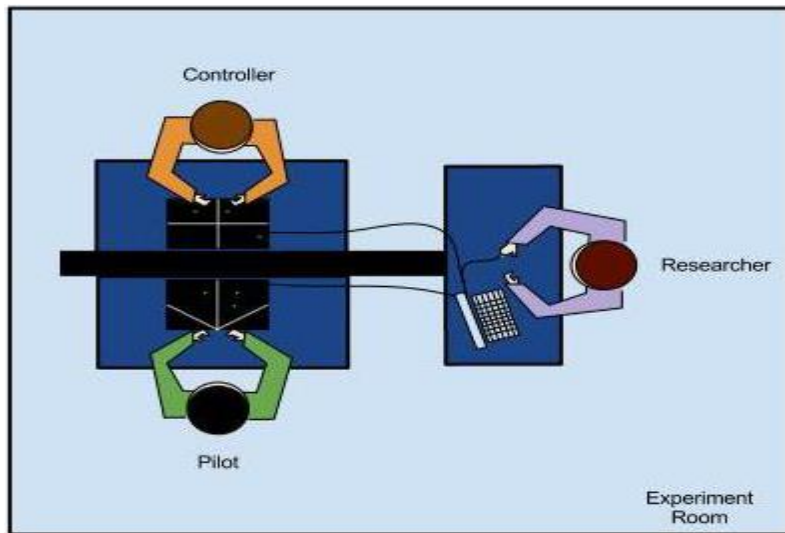


Figure 4-1: Preliminary study lab setup (Yuan & Histon, 2014)

The findings from the results of the preliminary study showed that longer time delay values such as 10 minutes had a clear effect on pilot-controller communication. Also, the findings showed that operator with the most up-to-date information had consistently better communication experience having less frustration, better communication effectiveness and performance. However, effects at smaller time delays of less than one minute were not discernible, due to limitations such as: 1) the lack of time pressure on participants as a result of static radar displays, and 2) the use of university students as non-expert participants lacking professional experience, knowledge and judgement (Yuan & Histon, 2014).

4.1.3 Proposal for a Follow-Up Study on Information Asynchrony

In light of the limitations, the preliminary study recommended repeating the study using a dynamic environment to provide critical time pressure to participants, as well as the use of SMEs instead of university students for more realistic and professional decision-making process. This provided the motivation for a follow-up study with the initial main research objective of finding the time delay where the effect of information asynchrony on pilot-controller communication becomes discernible. The follow-up study would use a dynamic ATC-Flight simulator. As a representative study for the proposed Integrated Modular Platform in Chapter 3, this study would be delivered online as an opportunity to evaluate its potential, and its acceptability to professional commercial pilots and controllers recruited as SME participants.

4.2 Case Study: Experiment Design

This section presents the experiment design of the follow-up study including participant tasks, experiment setup, scenario design, and recruitment. This section focuses on the experiment design requirements separate from requirements for online delivery (Section 4.3).

4.2.1 Simulator Environment

In each experiment session a pilot-controller participant pair would complete simulated tasks in a dynamic real-time collaborative environment. The study used a dynamic ATC-flight simulator environment delivered via the Integrated Modular Platform. An existing PC-based flight simulator was modified for this purpose. The simulator provided participants a video-only navigation display (Figure 4-2), and an ATC radar display (Figure 4-3) in a simulated TRACON operational environment. Each simulator screen had a primary display area, with a briefing paragraph on the starting traffic situation of each scenario on the top right corner of the screen. The ATC display only also showed flight strips at the bottom. Participants could read the briefing paragraph for up to two minutes, before performing simulator task for 3 minutes. The briefing disappeared during the trial to encourage participants to be focused on the screen.

The simulator flight operations were set around a fictional airport called “Campus Airport” with a single runway. Air traffic included airliners (Boeing 737), UAS, and bird flocks. Airliners are classified as cooperative objects, while the UAS and bird flocks are non-cooperative objects. Similar to the preliminary study, one of the pilot or the controller display had information asynchrony applied to the UAS and bird flock objects (non-cooperative objects).

An important aspect of the simulator design was to provide control to aircraft trajectory from an experimenter’ control panel in order to replicate real world operations from the air traffic controllers’ perspective. As a result, there was no means for participants to manipulate their own aircraft trajectory (pilot participant) or controlled aircraft trajectory (controller participant) through the browser. This is consistent with real-world operations for controllers, but is somewhat inconsistent with real-world operations for pilots.

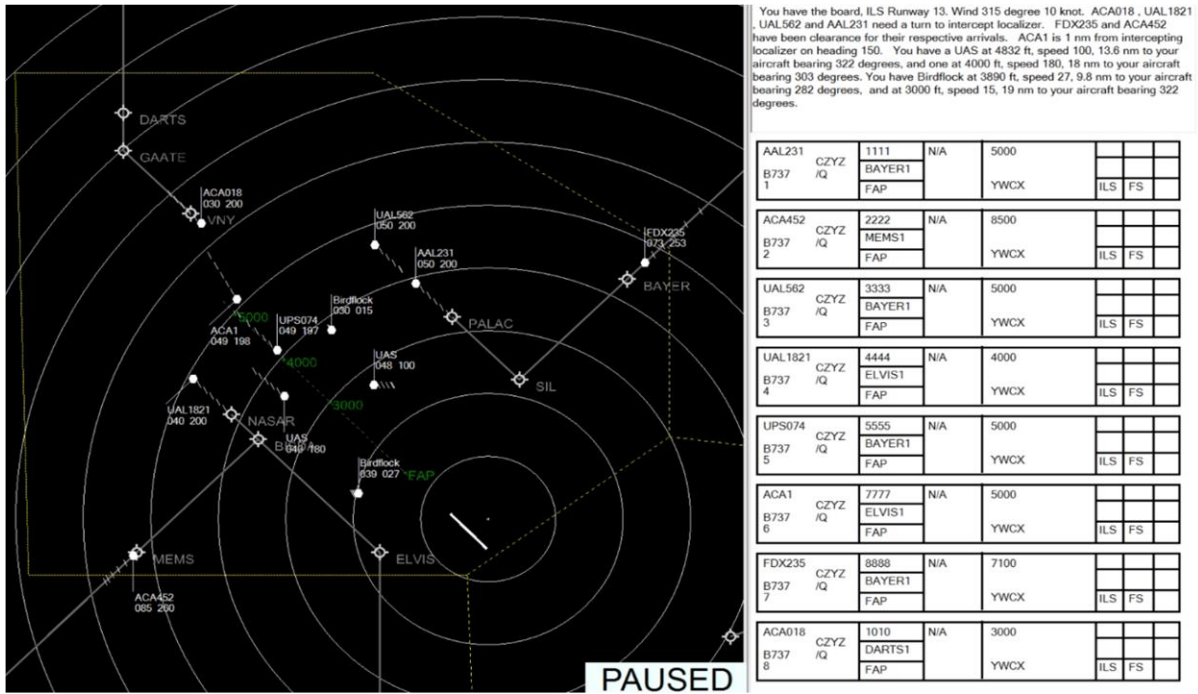


Figure 4-2: Controller participant's ATC radar display on the web

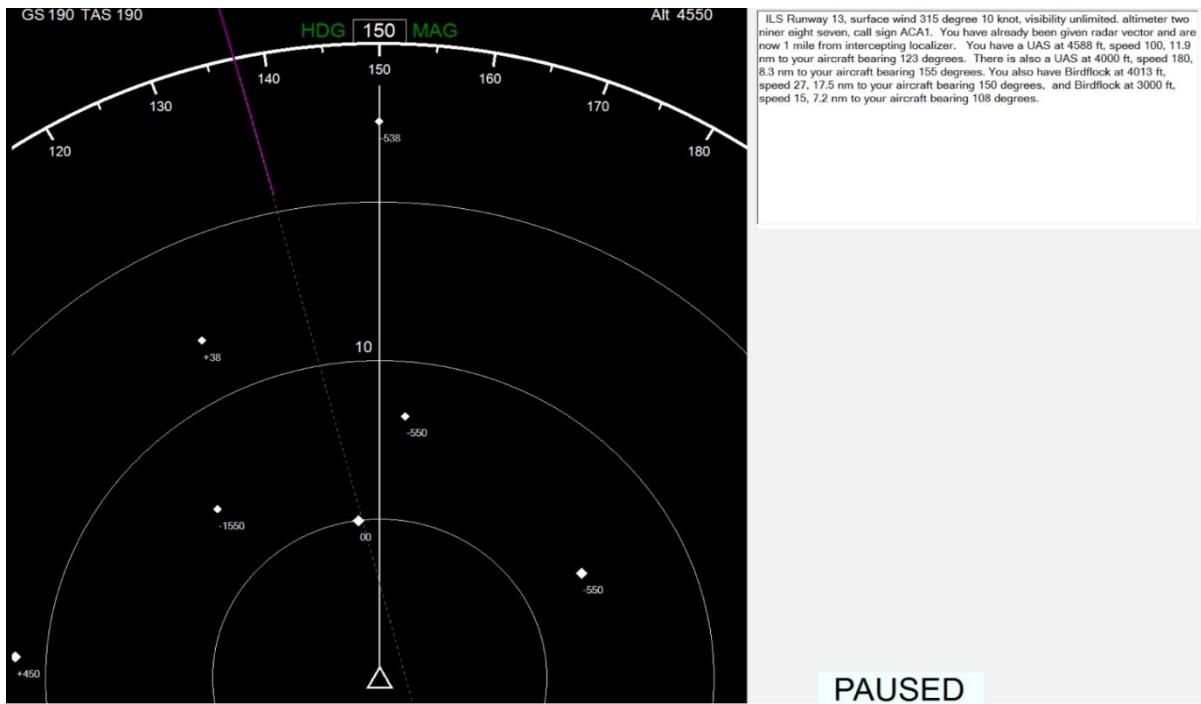


Figure 4-3: Pilot participant's navigation display on the web

Thus, a simulator procedure was designed by which voiced commands, from either the controller or pilot, would be fed back to the simulation software, thus providing aircraft trajectory control. To add plausibility, the experimenter played the role of “pilot flying” (PF), while the pilot participant would be the “pilot monitoring” (PM). For any intervention, the pilot participant would directly tell the experimenter to “descend to 5000” or “change heading 230.”

Finally, there was a design limitation with the controller’s display on the existing ATC-flight simulator on the PC; there was a lacking of tag-manipulation or zoom in and out functions implemented, due to time constraints in light of the complexity of such algorithms. As a result, controllers were unable to manipulate aircraft data tags and zoom in on surveillance targets clustered together on their display, unlike real-world operations. The controller participants were told to work with this limitation the best they can. For example, in case of multiple targets clustered together, the controller participants would ask to verify with experimenter for target information clarification. Controller participants were told to issue clarification requests such as “FedEx 031 please state your current altitude”, to which the experimenter would physically check the altitude of the target of interest and provide the appropriate read back.

4.2.2 Participant Tasks

The simulation environment was designed to immerse the pilot-controller participants in a realistic ATC-flight environment where they would be performing role-specific tasks consistent with their normal routines in real life operations. The pilot and the controller were instructed to communicate with each other as in normal operations to resolve any collision situations with any objects. All scenarios were designed so that one of the UAS would collide with the pilot participant’s aircraft by default (no control instructions given to deviate) at the 3 minute mark after trial start.

Controller participants were expected to separate all of the aircraft (cooperative objects) in his or her airspace while clearing either 1) arrivals to intercept localizer during arrival operations, or 2) departures to their assigned departure route during departure operations. This task would be done in light of UAS and bird flocks (uncooperative objects) with unpredictable behaviour in his or her airspace as the non-cooperative objects were designed to be non-responsive to instructions. Thus, the controller participant had to work to avoid collision of cooperative objects with both other cooperative and non-cooperative objects.

Pilot participants were expected to monitor traffic on the navigation display, and follow ATC instructions as in real life. He or she would be responsible for the safety of own aircraft only, with the call sign as “Air Canada 001” throughout the trials.

4.2.3 Experimenter and Confederate Tasks

In order to simulate the read backs to ATC instructions from all cooperative objects other than the pilot participant’s own aircraft, the experimenter took the role of being the pilots of all those aircraft. As well, the experimenter was responsible for controlling those aircrafts on the simulator to simulate corresponding behaviour according to ATC instructions. For example, with the ATC instruction “FedEx 031 turn right heading 230, descend and maintain 5000”, the experimenter would read back “right heading 230, descend and maintain 5000, FedEx 231”. Then, the experimenter would manipulate the simulator’s flight control panel to produce the desired aircraft behaviour. The experimenter was responsible for assisting both participants in controlling the simulator when needed. As well, the experimenter would lead participants through other post-trial and post-experiment data collection tasks during the simulator session.

Detailed information on the technical ATC-flight procedure are presented as briefing documents in Appendix F and Appendix G . The ATC-flight procedure was designed specifically to emulate the expected professional environment that professional pilots and controllers would normally work in.

4.2.4 Independent Variable: Time Delay Values

There were five time delay values used in the study (0, 6, 12, 48, and 96 seconds). The values were determined with the aim to provide one minimum (besides 0 seconds, referred to as “baseline”) and maximum value such that a non-effect and effect of information asynchrony can be guaranteed to be observed in theory, respectively. In each trial, participants were not told whether a time delay value had been applied, its value, or to whom.

Using the standard 3 nautical mile lateral and 1000 ft. vertical separation as reference, the choice of 6 second delay was chosen as minimum value as it translates to a lateral distance of 1000 ft. For a visual perspective for pilot and controllers, this would translate to about half the length of an aircraft target on the ATC radar screen, or the length of pilot’s own aircraft display symbol

(triangle). In this case, both parties would consider this a near miss, being well within the 3 nautical mile lateral separation rule.

The maximum time delay was chosen to be 96 seconds, translating to a discrepancy of approximately 3 nautical miles with the non-cooperative object at 100 knots. From the perspective of flight operation, this would mean a difference between separation standard being maintained and collision. In other words, pilots and controllers would theoretically be in conflict with one party trying to maintain separation while the other thought he or she is already doing so. All other values between 6 and 96 seconds were chosen in relation to the UAS update rate of 12 seconds in terms of radar hits.

Each time delay was applied to either the controller role, or the pilot role. This yielded the independent variable in the study, the nine possible time delays. The choices were labelled 96c, 48c, 12c, 6c, 0, 6p, 12p, 48p, 96p. The “c” and the “p” each represent the controller or the pilot getting the delay, respectively. The reason for this distinction was the assumption that a time delay applied to the surveillance data on the pilot side will not generate the same effect on communication as when applied to the controller side and vice versa.

4.2.5 Scenarios

The experiment was a within-subjects design. Each participant-pair completed two training trials as well as nine formal trials, one for each level of the independent variable (time delay value). To avoid participants simply learning where and when conflicts would occur, the traffic configuration in each trial was unique. Traffic configurations determined the starting point and trajectory of each aircraft in the scenario; they were carefully designed to be as equivalent in workload as possible, while still reflecting a range of possible aircraft positions. All configurations had only one designed-in conflict between a UAS and the pilot-participants aircraft.

The two training trials would each deliver a generic training scenario of either a departure or arrival operation without any time delay applied. However, for each of the nine formal trials, a unique traffic configuration (taken from a pool of five unique arrival traffic configurations (configurations 1-5) and five unique departure traffic configurations (configurations 6-10)) and a time delay value was randomly assigned. The assignment was pre-generated using the random list assignment service at <https://www.random.org/> (Random.org, 2015). Complete trial assignment is shown in Appendix K.

4.2.6 Dependent Variables

Dependent variables collected included both objective and subjective data collected during the simulator session, as well as post experiment surveys after completing all the formal trials.

4.2.6.1 Objective Data – Communication Recordings

Recordings were captured of the communications between participants in each formal trial. The recordings were transcribed and then analysed for the frequency of communication “events” thought to be indicative of a potential breakdown in communications. Specifically, spoken phrases were coded with six events, as shown in Table 4-1.

The hypothesis was that an increase in time delay would create an increase in the frequency of each type of event. For example, with a small time delay applied, the pilot-controller may start off by showing some conflicting understanding to a request, instruction or situational update from pilot or controller. The communication may progress through more phrases for clarification and confirmation as two parties work out the conflicting understanding. At this point, two parties may come up with a resolution in time before collision. However, with a larger time delay applied, the first three communication events may persist longer, with the communication evolving to include expression of confusion about the traffic situation. Finally, if still no resolution was found, urgency and finally interventional phrases may then start to appear, such as “I am descending NOW”, before near-miss or collision happens.

Finally, transcript coding were all done by a research assistant for consistency. The research assistant, who was also an experimenter of the follow-up study, was asked to take on this task as the person held a private pilot’s license (the author does not hold a one). The pilot experience was a great asset as the coding activity required understanding of the traffic situation that may influence the phrases spoken, particularly with phrases that may fit multiple events according to guidelines. This required judgement calls that was best made by someone who had formal pilot training and knowledge of ATC-flight operations, as well as having interacted first-hand with the professional pilots and controllers during experiments.

Table 4-1: Guidelines for audio transcript marking

Event	Guidelines
Conflicting understanding	Pilot-controller phrase exchanges showing conflicting understanding for traffic situation. An example include ATC issuing left turn heading 030 for intercepting localizer, while the pilot response that he was unable due to the maneuver putting him on collision course with an UAV 3 miles away, which the controller did not see. This pilot-controller exchange would count as one event.
Asking for clarification	Pilot or controller phrases asking for clarification to a previously-issued instruction or request for more details. An example include pilot descending immediately to avoid an UAV without informing controller. Controller then asked the pilot to clarify his or her intention for such descend. Another example can include pilot asking controller to clarify the details of a command issued. Here, one controller's or pilot's phrase would count as one event.
Asking for confirmation	Pilot or controller phrases asking for confirmation to a previously-issued instruction or request. An example can include controller asking the pilot to confirm his or her current altitude, or pilot asking the controller to confirm that the UAS was still in a turn. One pilot or controller phrase would count as one event.
Confusion to traffic situation	Pilot or controller phrases expressing confusion to traffic situation with hints such as unsure or hesitating tone and backtracking on instructions or request. One pilot or controller phrase counts as one event.
Expression of urgency	Pilot or controller phrases with urgent tone, and / or words used such as "expedite". The emphasis is a gradual speed-up of an existing process due to urgency, but allowing time for such speed-up. For controllers this may include phrases asking pilot to increase turn due to traffic appearing at 12 o'clock. For pilots, this may include phrases with urgent tone requesting a turn with a controller as an UAS closes in on distance.
Expression of intervention	Pilot or controller phrases expressing intervention. For the pilot, this would include informing controller that he or she is descending now as there were no time to wait for request. For the controller, this may include a command to a pilot to immediately top climbing and immediately descend now. The emphasis is on an immediate deviation from an existing process with no time for gradual speed-up.

4.2.6.2 Subjective Data - Post-Trial Questionnaire

A self-rated 7-point Likert (agree / disagree) post-trial questionnaire was collected after each of the nine formal trials for both pilot and controllers. Participants would self-rate against the questions presented in Table 4-2, according to their experience in the trial. A sample of the questionnaire for controllers and pilots are presented in Appendix B.

Table 4-2: Post-trial rating categories

Rating	Description
Confusion	Rate the statement that one felt confused with what the other party was telling one to do.
Awareness of own traffic situation	Rate the statement that one had a good understanding of own traffic situation around the airport.
Awareness of other's traffic situation	Rate the statement that one had a good understanding of the other party's situation around the airport.
Communication effectiveness	Rate the statement that one felt the communication between oneself and the other party was effective.
Satisfaction to initial resolution	Rate the statement that one felt satisfied to ATC's proposed initial resolution, or pilot's response to proposed initial resolution.
Satisfaction to final resolution	Rate the statement that one felt satisfied to ATC's proposed final resolution, or pilot's response to proposed final resolution.

The six self-rating questions were designed to capture the effects of information asynchrony on pilot-controller communications. It was hypothesized that an increase in time delay would increase the above captured effects on pilot-controller communication. For example, as time delay increased, it was expected that participants would feel more confused about the situation, experience decrease in situational awareness, communication effectiveness, and satisfaction to initial and final resolutions in light of collision conflict.

4.2.6.3 Post Experiment Surveys

In addition to the subjective data collection, participants completed two post experiment surveys after completing all nine formal trials. One post-experiment survey focused on professional

participants' insight and experience with information asynchrony in their professional work, as well as overall impressions of its effects during the simulator session. The second focused on their experience as a participant in an experiment using the Integrated Modular Platform (see Chapter 6). The first survey can be found in Appendix C and Appendix D as it had two versions for pilot and controller role. The second survey can be found in Appendix E as there was only a general version for all participants.

4.2.7 Recruitment

A core focus of the case study was recruiting professional pilots and controllers as SMEs. Specifically, professional pilots would include active or retired pilots with at least a Commercial Pilot License (CPL) or above. Professional air traffic controllers would include active or retired controller in working in either tower, TRACON or en-route environment. If a participant has both backgrounds, he or she was asked to pick a role to perform in the simulator.

In order to recruit these professional participants, different recruitment sources were used including professional blogs, LinkedIn groups, professional aviation organization and personal contacts. In terms of professional blogs, forums including LiveATC.net, propilotworld.com, airliners.net, PPrune.org, AvCanada.ca, and jetcareers.com were used as the source for recruitment. LinkedIn groups consisted of Aviation Professionals, Aviation Jobs - Aviationmatch, AVIATION Enthusiasts, Airline Pilots Group, Air traffic Control Network and Air Traffic Control (ATC) Jobs. For both recruitment sources, forum /group moderators were contacted for approval of recruitment letter, before recruitment posts were made in accordance to forum rules. Finally, professional organizations included Nav Canada and Air Canada. Recruitment emails were sent to relevant personnel acting as gatekeepers, and it was made clear that the study has no association with any of the major aviation bodies. Posts with link to the online study were circulated through internal blogs as per rules within the organization.

In the process, the participants were briefed about the study, as well as given consent information, before scheduling a simulator session with the experimenter. In addition, participants were screened to verify that they were qualified to be the SME that the study is looking for. Pilot and controller participant were randomly paired into a group primarily based on availability at a mutually convenient time.

4.3 Implementation of the Experiment Design Using the Integrated Modular Platform

This section documents how the Integrated Modular Platform was used to deliver the information asynchrony study on the web. The web environment setup is captured in Figure 4-4. The Integrated Modular Platform provided a means of providing each participant a unique visual stimulus, so they could only see their own display; this mimics the physical divider used in the preliminary study. The only interaction between participants was through online communications managed through the Integrated Modular Platform. Major topics in this section include: 1) pre-experiment activities, 2) implement decision within Integrated Modular Platform, 3) inserting participant commands into simulator, and 4) data collection implementation.

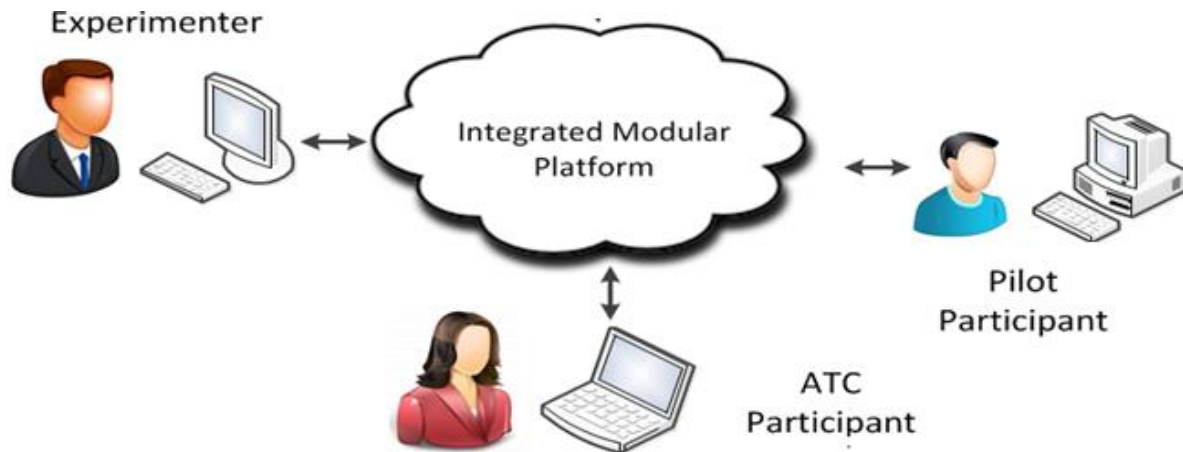


Figure 4-4: Experiment setting on the Internet

4.3.1 Pre-Experiment Activities Implementation

The key workflow components associated with pre-experiment activities are shown in Figure 4-5, according to the experiment design for recruitment in Section 4.2.7. The following sub-sections discuss key decisions made to implement this process using the Integrated Modular Platform.

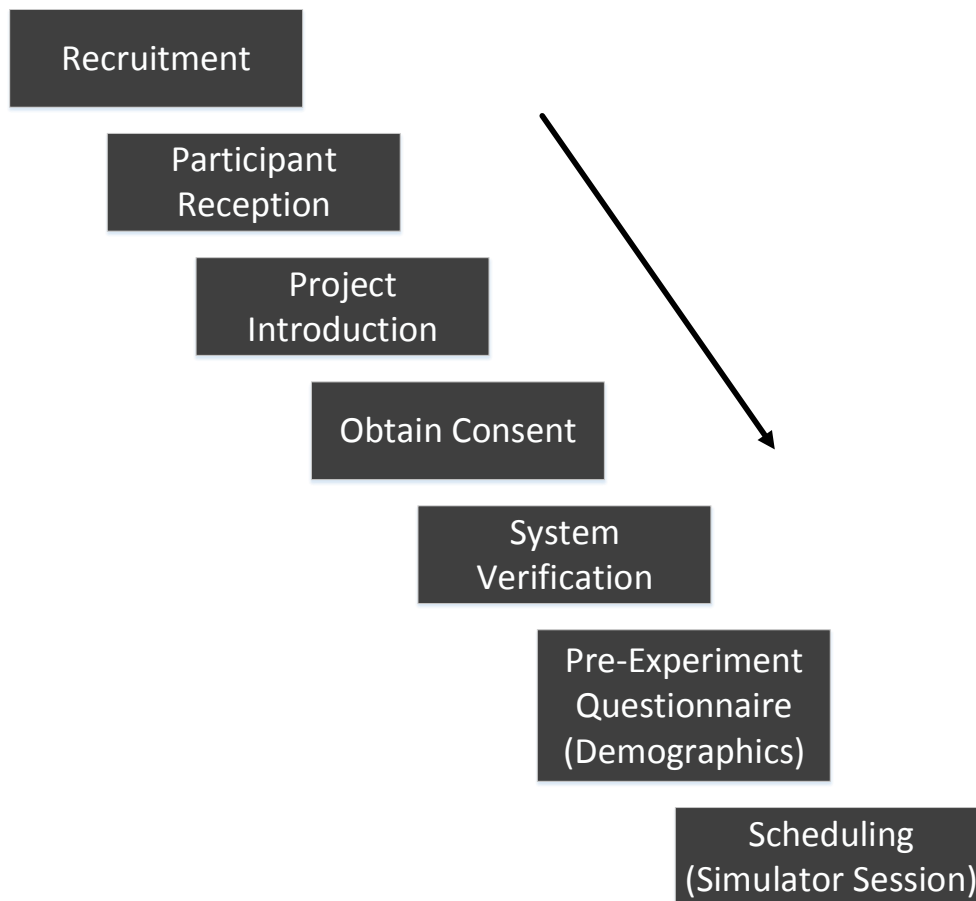


Figure 4-5: Workflow components for pre-experiment activities

4.3.1.1 Implementing Project Introduction, Obtain Consent and Pre-Experiment Questionnaire

Project introduction involved briefing participants through an information letter. As well, the experimenter would need to obtain consent from participants for the study as per ethics research requirement through formal consent forms. Finally, pre-experiment questionnaire, in the form of demographic survey, involved gathering participants' demographic information for later data analysis. Demographic information was also for SME screening (see Section 4.3.1.2).

As these three workflow components can be linked as project documents, the module utilized to generate the related experiment web pages was the Document Delivery Module. Page-link buttons were configured with an advanced link logic where participants must agree to all consent statements in the consent form in order for a "next page" button to appear. Otherwise, a "you cannot participate" button would appear to bring the participant back to the welcoming page. Similar advanced link logic

was configured too for the pre-experiment questionnaire web page where participants must submit survey in order for a “next page” button to appear. As for the web pages presenting project introduction documents, default HTML “next page” button was used.

4.3.1.2 Considerations for Screening Subject-Matter-Experts

As there was a requirement to recruit SMEs as opposed non-expert participants, a screening process was needed to 1) verify that a participant has an appropriate background, and 2) detect possible non-representative impersonators. Specific implementation details to achieve the above two goals are presented in the two sub-sections below.

For a potential participant to be qualified as SMEs for the simulator pilot role, one must hold at least commercial pilot license (CPL) level or above. For simulator controller role, the person should be working in at least one of En-Route, Tower or Terminal environment. Pilots with only private pilot license (PPL) or military without indicating at least CPL would not be allowed to join. All active and retired pilots and controller who met the requirements were all welcome, regardless of hours of experience.

The pre-experiment questionnaire, in the form of demographic survey, was used to screen potential participants with a question asking potential participants to indicate their professional background (see Question 3 in Appendix A). The power of using third party plug-ins was illustrated with the ease in which a built-in survey algorithm could be used to automatically accept or reject potential participants based on their responses. This is described in Figure 4-6.

In addition to verifying professional background, the researcher must also prevent non-representative impersonators from signing up. A combination of responses to the demographic questionnaire and participant language in follow-up emails was used. Questions in the demographic questionnaire asked participants for 1) current occupation, 2) country of occupation, and 3) current occupational status (active or retired). The responses were then compared with follow-up email responses by the experimenter for clues of authenticity during the interaction process to confirm participants scheduling. For example, the work schedule for major airlines was expected to be reflected in the availability of participants who had indicated their current occupation was flying for a major airline.

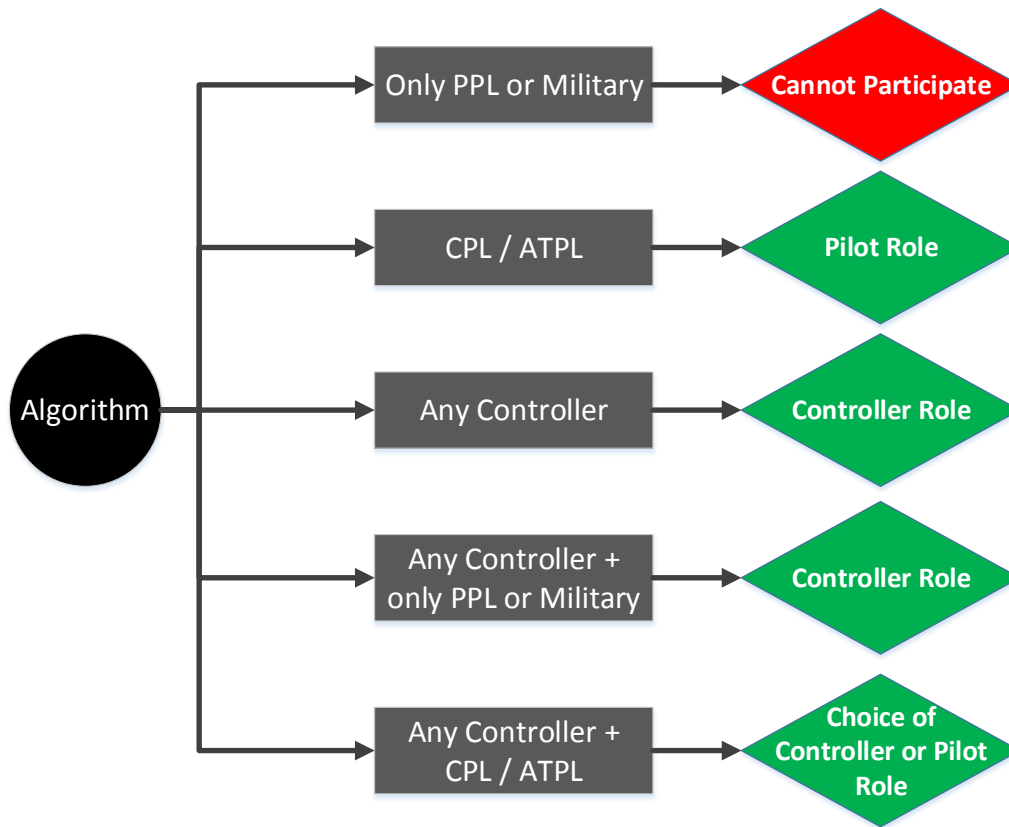


Figure 4-6: Survey algorithm qualifying professional participants

4.3.1.3 Implementing System Verification to Screen for Technical Requirements

As participants were using their own personal computers to participate in the experiment, it was important to insure that their system setup met a set of minimum technical requirements in order for the online simulator technology to function properly. This was implemented through a web page generated by the System Verification Module (see Figure 3-13). The technical requirements were usage of the Google Chrome browser, a Windows operating systems, and a network latency of less than 500 milliseconds (ms). Any participants who did not meet the requirement would not be allowed to participate in the simulator session.

The 500 ms requirement was chosen from a literature review of several study on the impact of network latency on gaming performance related to simulators. The findings all suggested that 500 ms was around the threshold to a noticeable worsening of performance. For example, Pantel & Wolf (2002) found 500ms was a point where the car in a multiplayer driving game became uncontrollable.

Similarly, Nichols & Claypool (2004) found that latency of more than 500 ms began to cause noticeably deteriorating player performance on collaborative multiplayer football game. Finally, author's in-game experience with Armed Assault 2 (Bohemia Interactive, 2015) simulator game showed a latency of 500ms contributes to noticeable difficulty²² in controlling vehicles.

4.3.1.4 Implementing Online Scheduling

The Online Scheduling Module was utilized to generate the experiment webpage responsible for participant scheduling. The third-party technology chosen for this module was the default SuperSAAS for its highly-customized templates (see Section 3.3.2.1.3). The scheduling calendar was configured for double slots in order for a pilot and controller participant to sign up for a common date. There are no page-link buttons specified for the experiment webpage as this would be the last web page associated with the pre-experiment activities, and one cannot be allowed backtrack to the pre-experiment questionnaire webpage to resubmit another demographic survey again.

Participants were asked to reserve the slot with his or her anonymous participant ID. After participants indicated their time slot on the online scheduler, the experimenter would then send a confirmation email to each of the participants confirming the slot. As well, the experimenter would enter the participants' ID into the login management system to be used as simulator session login username along with a unique password provided to them in the email.

4.3.2 Implementation of Simulator Session on the Web

This section focuses on the implementation decisions within the Integrated Modular Platform's modules in realizing the web simulator session on the web. First, a simulator session flow was identified (Section 4.3.2.1). Next, in order to deliver dynamic ATC-flight simulator environment on the web, a parallel process was used, with one process focused on delivering the communication capability, and the other process delivering the simulation display capability. The Online Conference Setup Module was used to generate web pages enabling online communication implementation (Section 4.3.2.2), and the Simulator Delivery Module was used to generate webpages enabling

²² 500ms was considered a severe latency value in the game as the ping monitor will highlight the latency value in red color as opposed to yellow (250ms) and green (<100ms) (Bohemia Interactive, 2015).

participant viewing of their role-specific display generated by the dynamic simulator (Section 4.3.2.3). Finally, data collection implementation are presented (Section 4.3.2.4).

4.3.2.1 Simulator Session Flow Implementation

In configuring the Integrated Modular Platform to deliver the experiment, an important consideration was developing a process to allow participant-pairs to progress through two training and nine formal trial while ensuring all data collection tasks were completed. The progress is illustrated in Figure 4-7.

The technology used in the Navigation Module and Document Delivery Modules alone was not sufficiently advanced to fully automate participant progress. The Experimenter's Session Control Module (see Figure 3-15) with the advanced link logic was used to control enable and disable buttons to deliver the above workflow components, such as controlling movement between a simulator output web page and the post-trial questionnaire web page.

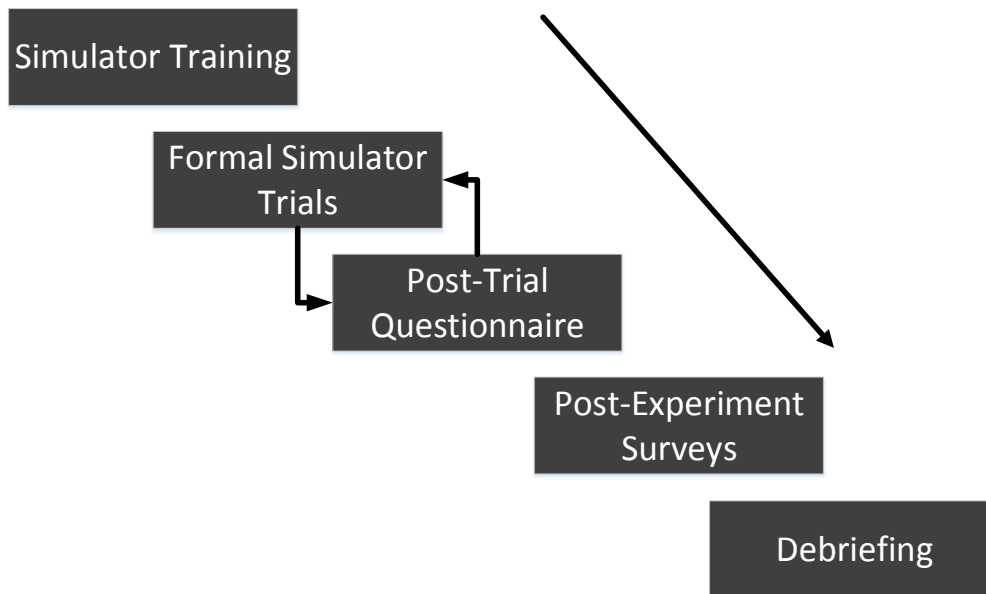


Figure 4-7: Simulator session procedure

4.3.2.2 Online Communication Implementation

In order to provide a communication channel between the experiment, pilot and controller participant, the online communication module was configured to use the default Google Hangout technology for its web-based login process (see Section 3.3.2.1.4). The module generates an online

conference set-up webpage and a chat window (i.e. Google Hangout chat interface) which remains opened in parallel to other workflow components. Using a headset, participants would be able to communicate with each other and the experimenter on the web. As well, in order to replicate the lack of visual contact in real-world operations, participants should not see each other; consequently, participants were told to turn off their camera in Google Hangout.

4.3.2.3 Dynamic Simulator Display Implementation

The dynamic simulator displays provided to the pilot and controller's browser were implemented as follows. Two unique virtual "simulator" rooms were first created by the experimenter through the experimenter's session control module for participants to join. This is shown on the "room list" webpage generated by the module (see Figure 3-14). After joining, each participant would see his or her own dynamic simulator display shown in a full-screen online video player. The experimenter controlled the enabling / disabling of the "next page" button on the "room list" webpage to set when participants proceeded to a post-trial questionnaire, or returned to the simulator delivery module for the next trial.

There were two risks identified with this implementation. First, there was a risk of participants joining the wrong room (e.g. pilot joining controller room and viewing their display instead of the pilot display). However, it was expected, and turned out to be the case, that professional participants would be mature enough to let the experimenter know and this was easily corrected. Second, while it was possible for participants to open two browsers and in theory have a navigation display and an ATC radar display opened side-by-side, again professional participants were assumed to be mature enough not to do this.

4.3.2.4 Measuring Network Latency in an Online Environment

Due to the inherent latency in an online environment, an interesting challenge was encountered where the latency may affect the accuracy of time delay values administered to the trials. More specifically, the network latency would affect the time delay in information seen by the pilot and controller. For example, with a 6 second time delay value applied to the pilot participant, the pilot participant may have a network latency (between his and experimenter's internet location) of 2 seconds, while the controller participant has 6 seconds. Here, the difference is 4 seconds, and must be added to the 6 second time delay value. Thus, in reality, a 10 second time delay value would be

experienced by the pilot participant. This can be expressed by the modified information asynchrony diagram to include the network latency consideration, as captured in Figure 4-8.

In order to work around this problem, a restriction of no more than 2 seconds in network latency difference between pilot and controller was set. Participants would be asked not to participate in the simulator session if the discrepancy exceeded the restriction, or the fluctuation was too high. If during simulator session, it was detected that network latency exceeds restriction, the pilot-controller group would still proceed with the session, but not have their subjective ratings from post-trial questionnaire and objective data from recorded communication transcript included in data analysis for Objective 4. However, answers to post-experiment surveys would still be considered in data analysis for lessons-learned critique on the Integrated Modular Platform.

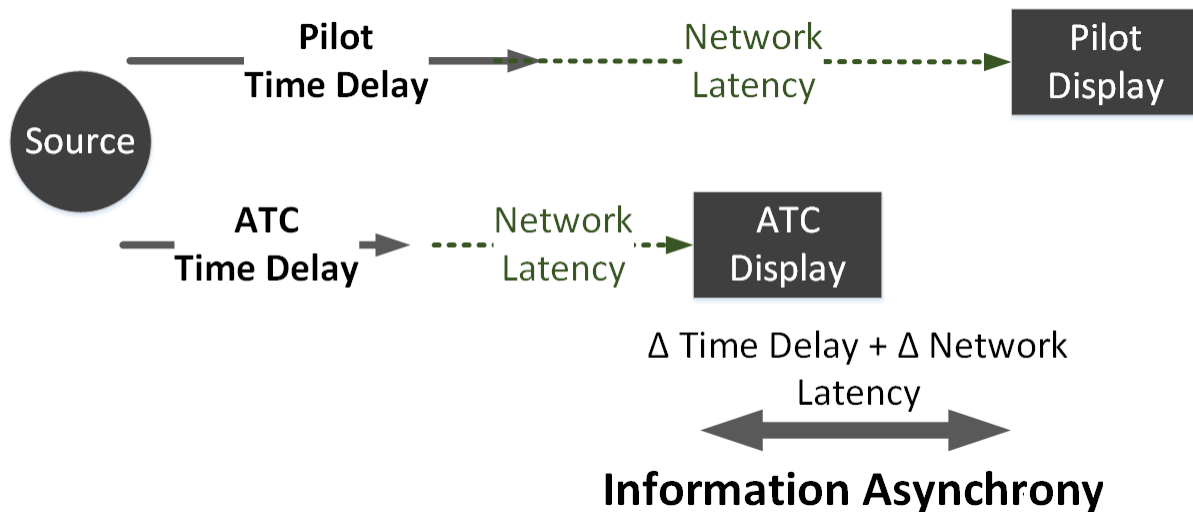


Figure 4-8: Information asynchrony diagram with network delay consideration

After challenges were experienced implementing automatically measured latencies, and due to the need to capture the latency specifically associated with the software generating the streaming of video data, a simple cross-check technique was developed. Participants were asked to do a quick counting test with an online clock broadcasted through the simulator screen to them prior to the formal simulator trials. Each participant would count out loud the ticking seconds for a 6 second duration. The discrepancy between the counting and what the experimenter sees on the online clock image that was being transmitted to the participant was then recorded on a spreadsheet. The 6-second duration was to also capture the fluctuating nature of the network latency. This test methodology was simple to implement and robust for the accuracy that was required for this study.

4.3.3 Data Collection Implementation

In order to realize the objective data collection as mentioned in the Section 4.2.6.1, a physical audio recorder was used to record the conversation for objective data collection. An online recorder was part of the default features on the experimenter's session control module. However, this was deemed to be unreliable as the browser would sometimes freeze when the recording size exceeded 3 minutes. Thus, the physical audio recorder was used instead.

To realize subjective data collection for post-trial questionnaire and post-simulator surveys, the Document Delivery Module was used to deliver the questionnaires and surveys on the web using FluidSurveys™ as the third-party online survey service, with reasons mentioned in already in Section 3.3.2.1.2. Advanced link logic were configured to generate “simulator trial” and “post-trial questionnaire” experiment webpages with the experimenter able to enable and disable the button to control participants' progress. As for experiment webpages for post-experiment surveys, a “next page” button would only appear after participants submitted their responses.

4.4 Chapter Summary

The implementation of the follow-up study to Yuan & Histon (2014)'s preliminary study on information asynchrony was presented in this chapter. It included details on how the Integrated Modular Platform was used to deliver the follow up study online. The major experiment design requirements were presented as well as how they were realized by specific modules. Third-party technologies were also identified for key platform modules. The following chapter describes the results of the experiment, while Chapter 6 presents the lesson-learned critiques as a result of evaluating the platform to deliver the experiment.

Chapter 5

Results of Follow-Up Study on Information Asynchrony

This chapter presents the results and findings of the case study experiment on information asynchrony. As reflected in Objectives 4, the study sought to answer the research question of whether there is a generally observable effect of information asynchrony on pilot-controller communication with an increase in time delay value.

This chapter is organized as follows. Section 5.1 presents demographic information from the subject-matter-experts participants. Section 5.2 and Section 5.3 present the subjective and objective data analysis details, respectively. Finally, Section 5.4 presents discussion on any implications and findings from the analysis results in answering the research question.

5.1 Participant Demographics

A total of 26 participants, forming a total of 13 pilot-controller groups, participated in the experiment. 92% of the participants were male, while 8% were female, with an average age of 46.5. 85% of participants came from North America (evenly split between US and Canada), while 15% came from Western Europe.

For the pilot participants, 77% held Airline Transport Pilot License (ATPL), while 23% only held a Commercial Pilots License (CPL). Four of the pilot participants who held an ATPL also held a military pilot license as well. One of the pilot participants had previously worked as a terminal and tower controller. The most recent occupation of pilot participants is shown in Table 5-1.

Table 5-1: Most recent occupation indicated by pilot participants

Occupation	% of Pilot Participants (n = 13)
Airline pilots	68%
Flight instructor	8%
Military pilot	8%
Medivac pilot	8%
Private pilot but holding CPL	8%

For the controller participants, 54% of the participants were from North America (evenly split between US and Canada), and 23% from Western Europe. The remaining 23% of participants were from Czech Republic, South Africa, and Australia. 85% had experience with en-route control, while 77% had experience with tower control, and 54% had experience with terminal (TRACON) control (participants indicated all types of ATC they had previous experience with). 30% of the participants were also pilots holding at least a CPL. The most recent occupation indicated by controller participants at the time of recruitment is presented in Table 5-2.

Table 5-2: Most recent occupation indicated by controller participants

Occupation	% of Controller Participants (n=13)
ATCO supervisors	23%
En-route controller	23%
Tower controller	15%
ATC consultant	15%
Terminal controller	8%
ATC trainee	8%
Aviation journalist	8%

5.2 Analysis of Participants' Subjective Rating Responses

To answer the research questions, analysis was conducted on subjective rating responses from post-trial questionnaire, as well as objective measurement of the effect of information asynchrony through communication events. As stated in Section 4.2.6.2, the main source of subjective data collected included self-rating 7-point Likert scale agree/ disagree post-trial questionnaires on six rating questions. The six self-rating questions were designed around characteristic effect of information asynchrony on pilot-controller communications. A sample of the questionnaire for controllers and pilots are presented in Appendix B. First the analysis methodology is discussed (Section 5.2.1.1), followed analysis presentation (Section 5.2.1.2).

5.2.1.1 Analysis Methodology

5.2.1.1.1 Data Sample Consideration

Of 13 pilot-controller groups in the study, subjective data collected from two groups were not included in the data sample for analysis. One of the groups had incomplete post-trial questionnaire submissions. For the other group, the network latency difference between pilot and controller participant tested during simulator session was beyond the limit of less than or equal to 2 seconds. The 2 seconds limit was set due to the gap between smaller time delays of 0, 6, and 12 seconds (see Section 4.3.2.4).

5.2.1.1.2 Approach

The analysis was most interested in examining participants' rating responses as the time delay increased. As a review, the hypothesis is (see Section 4.2.6.2) that an increase in time delay would result in increase of the effect of information asynchrony on pilot-controller communication.

To test this hypothesis, the analysis sought to determine if there was a statistically significant difference between relative rankings of each rating response (score) as time delay increased from the perspective of "I am ahead" and "I am behind" in each of pilot and controller group. Here, "I am ahead" perspective refers to time delay applied to the other role's participant (i.e., from a vintage point of pilot role, controller role has the time delay applied to it), while "I am behind" perspective refers to time delay applied to own role (i.e., from a vintage point of pilot role, the pilot role itself has the time delay applied to it). In the analysis, the "I am ahead" perspective corresponds to time delay values of 6, 12, 48 and 96 seconds, while the "I am behind" perspective corresponds to -6, -12, -48 and -96 seconds.

In the analysis, the subjective rating responses from pilot and controller participants were treated as two separate groups for analysis ($N = 11$ for each group) and were not combined. Since pilots and controllers participated as a pair, combining the responses would introduce a dependence between observations, undermining the assumptions for statistical hypothesis testing. Friedman's Test was chosen to test that the scores for each group for each time delay condition were drawn from a population with the same median (Berenson, 2011; Howell, 2013). The choice of Friedman's Test was due to the presence of extreme outliers and that the data was not normally distributed. For post-hoc tests, a Wilcoxon Sign-Ranked test with Bonferroni correction was used to further

determine where the significant difference occurs, if Friedman's Test yielded significant result (Howell, 2013). As well, ratings from both groups for each time delay value would also be compared to see if there was significant difference between the observed effects as seen in each group if there was significant effect observed in both groups. Wilcoxon-Signed rank test would be used due to the paired nature of pilot and controller group (Howell, 2013).

5.2.1.2 Analysis Presentation

The six rating questions were mentioned in Section 4.2.6.2. They are restated here for review: Q1) rate the statement that one felt confused with what the other party was telling one to do, Q2) rate the statement that one had a good understanding of own traffic situation around the airport, Q3) rate the statement that one had a good understanding of the other party's situation around the airport, Q4) rate the statement that one felt the communication between oneself and the other party was effective, Q5) rate the statement that one felt satisfied to ATC's proposed initial resolution, or pilot's response to proposed initial resolution, and Q6) rate the statement that one felt satisfied to ATC's proposed final resolution, or pilot's response to proposed final resolution.

Figure 5-1 shows a sample of 7-point Likert rating responses to the statement from pilot group for Q1 across all time delay conditions. Rating responses for all six questions from both pilot and controller groups can be found in Appendix H. As well, Figure 5-2 and Figure 5-3 show the rating median at each time delay condition in Q1 and Q6 for pilot and controller group, respectively.

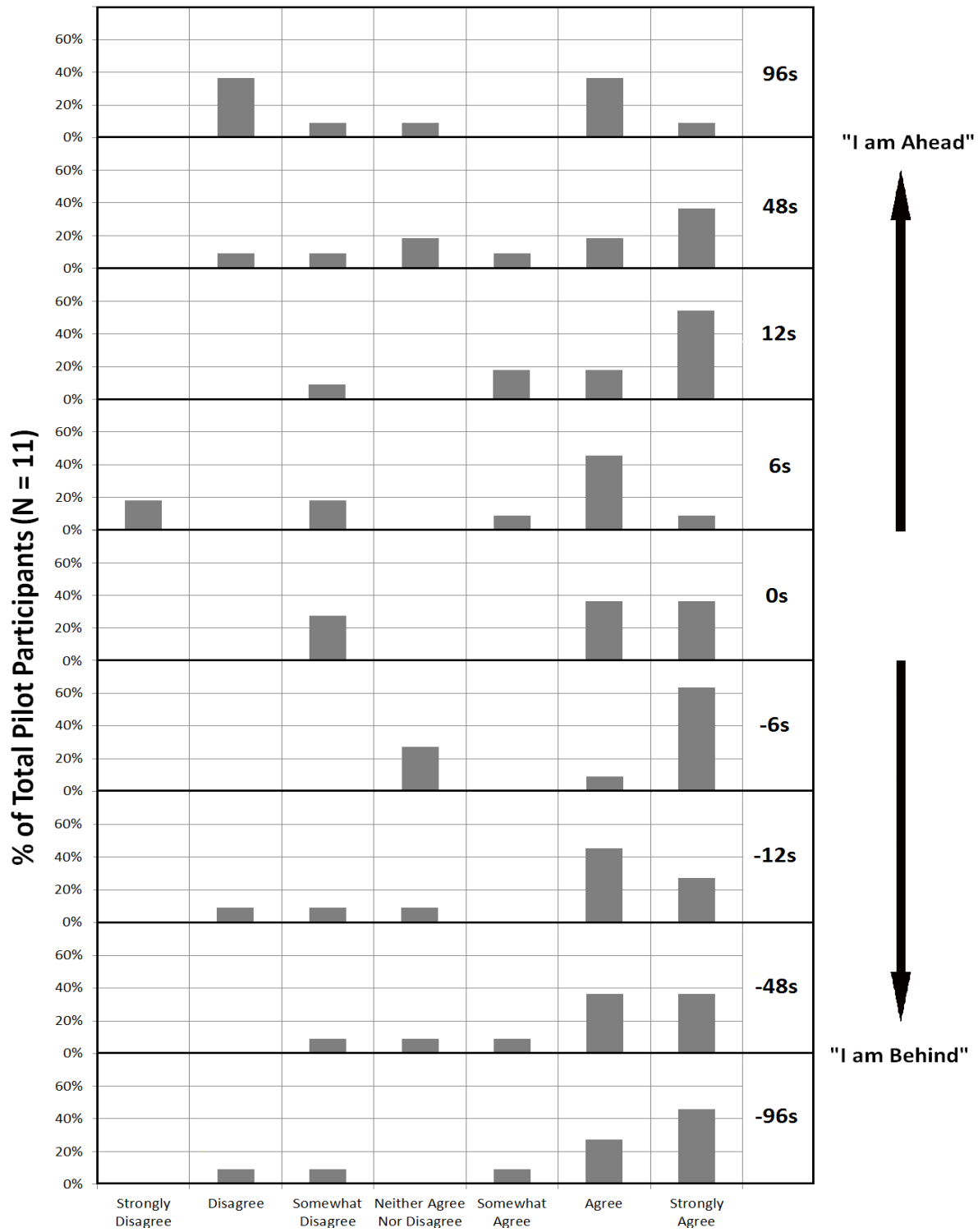


Figure 5-1: Pilot participants' raw rating responses to the statement that they felt confused about the traffic situation (note "Agree" means more confused)

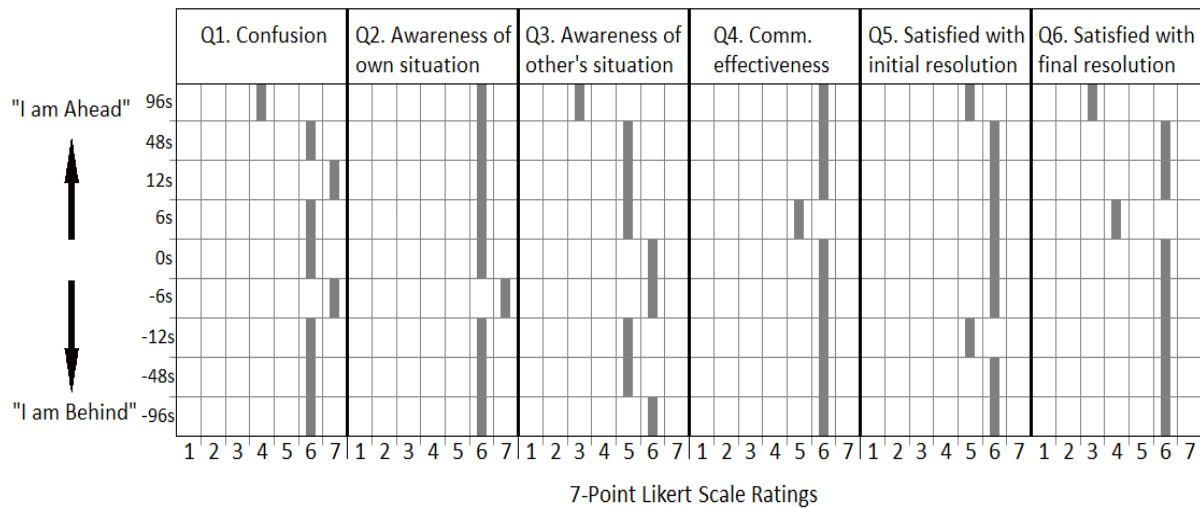


Figure 5-2: Graph of rating medians for all time delay conditions for pilot group (1 = strongly disagree, 7 = strongly agree)

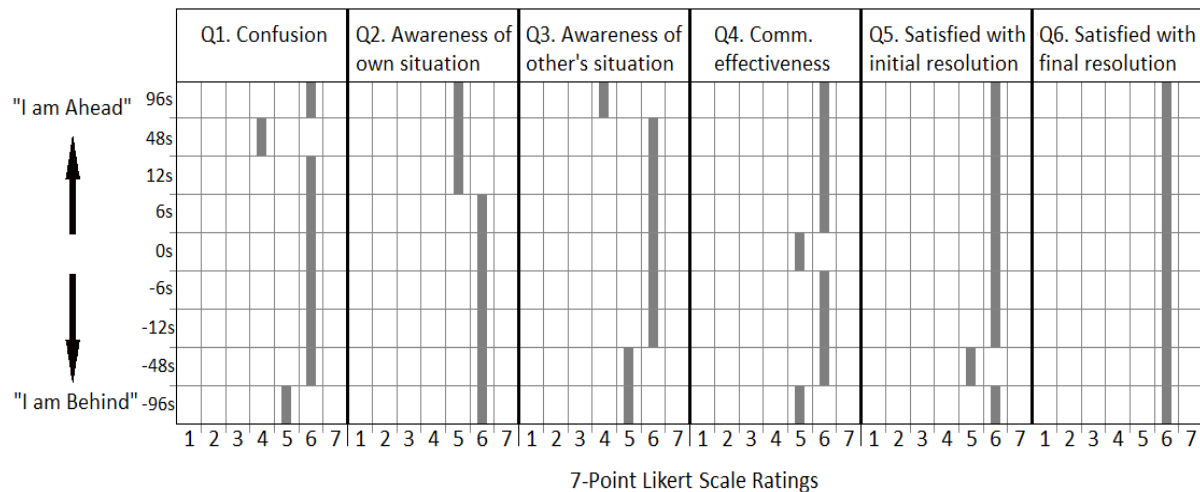


Figure 5-3: Graph of rating medians for all time delay conditions for controller group (1 = strongly disagree, 7 = strongly agree)

From visual inspection, all the figures showed large noise, thus making it difficult to discern substantive differences between the rating responses as time delay value increases towards each of the extreme values of "I am ahead" and/or "I am behind." As for Figure 5-2 and Figure 5-3, visual inspection does not show a large difference between median. However, there may be a slight trend of more effect of information asynchrony for pilot's group captured in Q3 and Q6 (awareness of other's traffic situation, and satisfaction to controller's final resolution). A Friedman's test was performed on rating responses from pilot and controller group for each of the six rating questions in

post-trial questionnaire. The results showed no significant difference in the median of the rating response across all nine time delay conditions between -96 and 96 seconds, as summarized in Table 5-3 below.

Table 5-3: Results from Friedman’s Tests on rating responses from post-trial questionnaire

	Pilot Group	Controller Group
Q1	$\chi^2(8) = 13.763, p = 0.088$	$\chi^2(8) = 4.358, p = 0.823$
Q2	$\chi^2(8) = 5.612, p = 0.691$	$\chi^2(8) = 3.624, p = 0.889$
Q3	$\chi^2(8) = 6.715, p = 0.568$	$\chi^2(8) = 7.564, p = 0.477$
Q4	$\chi^2(8) = 6.824, p = 0.556$	$\chi^2(8) = 4.600, p = 0.799$
Q5	$\chi^2(8) = 6.285, p = 0.615$	$\chi^2(8) = 7.667, p = 0.467$
Q6	$\chi^2(8) = 9.370, p = 0.312$	$\chi^2(8) = 2.236, p = 0.973$

5.3 Analysis on Objective Measurements

As stated in Section 4.2.6.1, the main source of objective data collected included audio transcripts recorded during each of the nine formal simulator trials. The transcripts were analysed for measurable characteristic of communication “events” as signs of effect of communication. Here, spoken phrases were marked for: 1) expression of conflicting understanding, 2) asking for clarification, 3) asking for confirmation, 4) expression of confusion to traffic situation, 5) expression of urgency, and 6) expression of intervention. The analysis methodology is first presented, followed by analysis presentation.

5.3.1.1 Analysis Methodology

5.3.1.1.1 Data Sample Consideration

Of all 13 pilot-controller groups in the study, objective data collected from two groups were not included in the data sample for analysis. One group had incomplete recordings due to the unreliability of the embedded online recorder in the experimenter’s session control webpage (physical recorder was used for all other groups). For the other group, the network latency difference

between pilot and controller participant tested during simulator session was beyond the limit of less than or equal to 2 seconds. The 2 seconds limit was set due to the gap between smaller time delays of 0, 6, and 12 seconds (see Section 4.3.2.4).

5.3.1.1.2 Approach

The analysis was most interested in the change of number of communication events in all audio recordings from the baseline condition in each of pilot and controller group (N = 11). As mentioned in Section 4.2.6.1, the hypothesis is that an increase in time delay would create an increase in the frequency of each type of event. In relating this to the hypothesis, it is expected that there will be an increase in change of number of events as time delay increased towards the perspective of “I am ahead” and “I am behind” in each of pilot and controller group. Here, “I am ahead” perspective refers to time delay applied to the other role’s participant (i.e., from a vantage point of pilot role, controller role has the time delay applied to it), while “I am behind” perspective refers to time delay applied to own role (i.e., from a vantage point of pilot role, the pilot role itself has the time delay applied to it). In the analysis, the “I am ahead” perspective corresponds to time delay values of 6, 12, 48 and 96 seconds, while the “I am behind” perspective corresponds to -6, -12, -48 and -96 seconds.

To test this hypothesis, the aim was to look at whether there was a relationship between the increase in number of events and increase in time delay values. Specifically, the analysis sought to look at whether the observed difference between changes of number of communication events was statistically significant depending on time delay conditions. Here, a Friedman’s Test was chosen due to extreme outliers and with data not normally distributed. Wilcoxon Signed-Rank Test with Bonferroni correction was used as post hoc analysis if Friedman’s Test yielded significant result (Howell, 2013). Visual inspection was also conducted to look at whether there was an observable difference in the deviation change of values between pilot and controller group. If there is such hint from visual inspection, Wilcoxon-Signed-Rank Test would be used to determine whether this difference is statistically significant, due to the paired nature of pilot and controller group (Howell, 2013).

5.3.1.2 Analysis Presentation

The change in number of communication events for both the pilot and controller group is presented in Figure 5-4. A random value between 0 and 0.35 was added to each change in number of

communication event values in order to present the spread concentrations. Figure 5-5 presents the medians of the change of number of communication events at each time delay condition for both pilot and controller group.

From visual inspection, one can see the majority of the change in number of communication events concentrated between -3 and 3 (approximated by red horizontal lines), as well as large spread for all time delay conditions, with some values beyond 4 and -4. Thus, there was not a distinctive increase or decrease in terms of number of communication events as time delay increases in both direction, visually. This observation can be further supported in Figure 5-5 with minimal deviation between medians. A Friedman's Test was performed, with the result showing that the observed difference between change in number of communication events at each time delay value was not statistically significant ($\chi^2(8) = 4.579, p = 0.843$ for pilot group, and $\chi^2(8) = 3.248, p = 0.918$ for controller group).

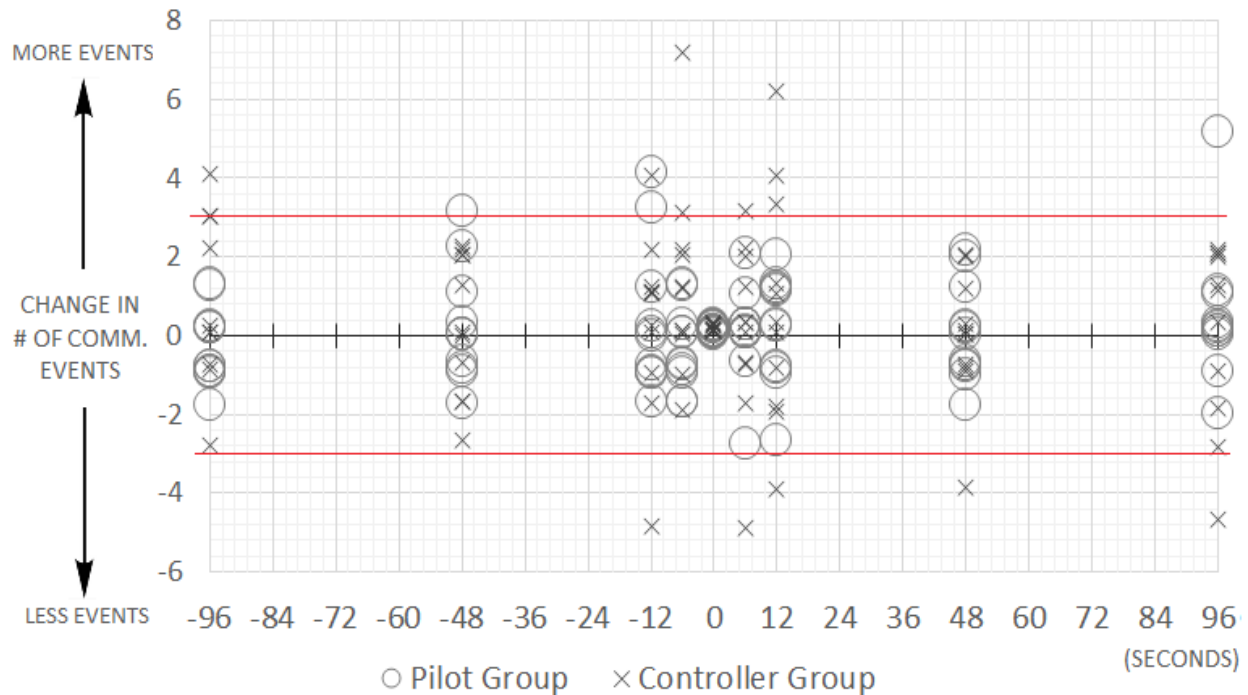


Figure 5-4: Scatter plot for change in number of communication events from baseline condition, regardless of simulator roles and who is ahead or behind

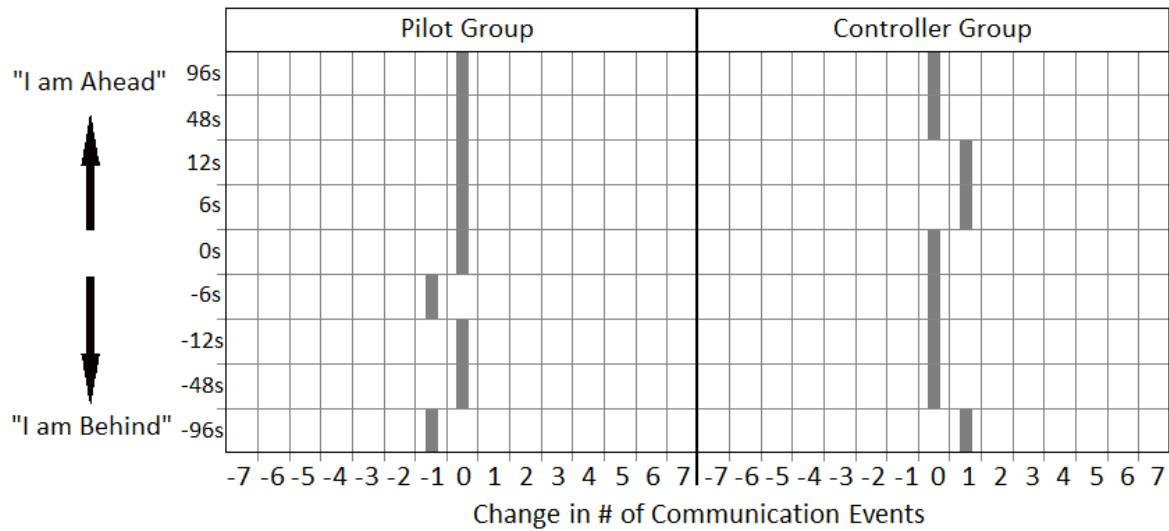


Figure 5-5: Graph of medians of change in number of communication events for all time delay conditions for both pilot and controller group

5.3.2 Discussion

The results from the above analysis on both subjective and objective data showed that there was no generally observable effect of information asynchrony in pilot-controller communication as time delay increased. This was based on the definition of “observable effect” in Objective 4. Here, possible factors contributing to the result from the analysis were identified in terms of participants’ performance, difficulties with maintaining consistent simulator procedure, and limitations to measurement of information asynchrony.

5.3.2.1 Participants Performance

In terms of participants’ performance, there were both positive and negative aspects that may have contributed to the lack of observable effect of information asynchrony.

5.3.2.1.1 Positive Aspect

One positive aspect was that a majority of participants using strategies as representative working practices to that of in real life to mitigate the effect of information asynchrony. The strategies included projection of future likely target position, as well as advanced planning of an ongoing situation for divergence and more separation space. The strategies were mentioned by the participants in the post-experiment surveys as similar or same to what they’d do in real life. Thus,

this may have contributed to the limited effect of information asynchrony observed in the result.

Example comments included:

- *Aircraft speed and performance is more affecting than an asynchrony. Asynchrony delay is often absorbed by the advance time you take to plan ongoing situation.*
- *Mental projection of the latest information to get a "best guess" of traffic location.*
- *Separation standards are set with data lag in mind; we could probably safely run aircraft closer together if we were assured of more up-to-date information. Most controllers normally add a little bit of extra space between their aircraft to ensure that the proper spacing will exist because we know that there is a delay in radar updates.*
- *Proceed as cleared by the control if safe to do so. If not deemed safe use the next best corrective action by either diverting from clearance to avoid collision.*

The positive aspect of this was that the online simulator environment successfully captured representative information asynchrony for participants to ‘work with’, and that the recruitment of subject-matter-experts helped to evaluate the effect of information asynchrony in a more realistic setting. One significance of this may mean that the choice of 96 seconds may not be enough to guarantee a distinctively observable increase in effect from other smaller time delays, as participants were able to mitigate the effect up to such asynchrony value more effectively than assumed. Higher values should be explored in future studies (such as 5 minutes).

5.3.2.1.2 Negative Aspect

The negative aspect of participants’ performance was more related to the realism constraints in the simulator environment that affected decision-making, contributing to the wide variability in the collected data and the lack of observable effect. However, it is important to point out that these were more experiment design and technical limitations that can be addressed in the future, not inherent limitation with online simulation that cannot be addressed. There were four constraints pointed out by participants in the post-experiment surveys.

The first two constraints were related to environmental cues. Specifically, these included: 1) the absence of cues such as visual, out-the-window view for pilots, and 2) the inability to discuss situation in a pilot-co-pilot crew environment. For the first constraint, all the scenarios were assumed to be

night operation, where there was no out-the-window-view implementation on the simulator. This may have limited pilot participants' ability to use visual cues as verification aid and for 'see and avoid', thus affecting accuracy in decision-making. Representative comments include:

- *I'm unable to visually spot out traffic/birds like I would in my work (VFR), so I am unable to simply see and avoid.*
- *Any evasive actions done in my work are mainly "see and avoid", or do as the controller instructs, whereas in the simulator trial I had to take action based on a display I don't use in my work.*

For the second constraint, the single pilot operation prevented the pilot participant from discussing with a co-pilot for more informed decision-making on traffic situation and instructions from controllers. One representative comment include:

- *Confusion over role - In my real work environment, I communicate with the other pilot. We both watch and analyze what we are seeing, which makes it easier to make informed decisions.*

The third constraint was on the unfamiliarity of the new ATC-flight environment including maps. This may have influenced the accuracy of the decision-making as participants took time to get use to the workings of manoeuvring aircrafts around the airspace even after training. This was both observed by the author and also from representative participants' comments including:

- *The displays and indications are not exactly what I'm used to seeing.*
- *I was not familiar with the airspace and not comfortable working around problems.*

Finally, the fourth constraints was related to a technical limitation with the simulator. Particularly, participants pointed out the lack of direct control of simulator for participants to directly manoeuvring aircrafts without the need to tell experimenter to do that, as well as declutter surveillance targets on ATC radar screen through zooming or adjusting tag orientation. This may have prevented more accurate decision-making due to the inability to more accurately take appropriate action to ongoing situation, or discern which target is where on the radar screen from the clutter. Representative comments are as below:

- *Inability to manually maneuver the aircraft if needed.*
- *Labels overlapping, hard to see data (callsigns, altitude).*

5.3.2.2 Difficulties with Maintaining Consistent Simulator Procedure

The author observed difficulty in maintaining a consistent scenario procedure tailored to the collision designed into each scenario. This appeared to be due in part to varying control strategies used by participants due to their different background, experience and training from region of work (e.g. Africa vs North America). For example, the author observed that given the same scenario, some controller participants issued climb instruction to pilot participant for direct climb to 12,000 feet after radar contact, while others may opt for more step-climb approach. Consequently, this may have contributed also to the large noise observed in the 7-point Likert rating responses and wide spread of change in communication events. This can be seen as another study limitation associated inherit with recruiting professional participants internationally.

5.3.2.3 Limitations with Measurement of Information Asynchrony

In terms of limitations with the measurement of information asynchrony, one factor identified was the current measures for information asynchrony being not robust enough to the inherent variability in working methods and communication styles. Examples included varying details in instruction given, as well as how some participants spoke a lot, while others spoke only a little, in the same given simulator scenario.

Another factor was the limitations of time delay in having direct effect on communications to professional participants. This can be supported by how pilots and controllers directly observe the history and current positions of surveillance objects (assuming no out-the-window view) to form a mental model of the situation and behaviour of the aircrafts (Reynolds, 2006). Here, time delay ultimately manifests itself in a difference in the physical location of an object on the display screen, compared to the object's 'actual' location. This can be described by the following relationship as captured in Equation 5-1. The change in physical location between displayed and 'actual' measured in pixels (ΔP) is a function of the speed of the object (UAS in this case), the display size-to-map-range ratio, and time delay (ΔT).

$$\Delta T \times UAS\ Speed \times \frac{\# \text{ of pixels in height of radar display}}{\text{Display map range}} = \Delta P$$

Equation 5-1: Relationship between time delay and pixel difference

Thus, rather than designing the experiment around consistent time delay values, it may be more appropriate for future follow-up studies to design for consistent screen distance as a more direct-impact measurement on information asynchrony. This is captured in Figure 5-6.

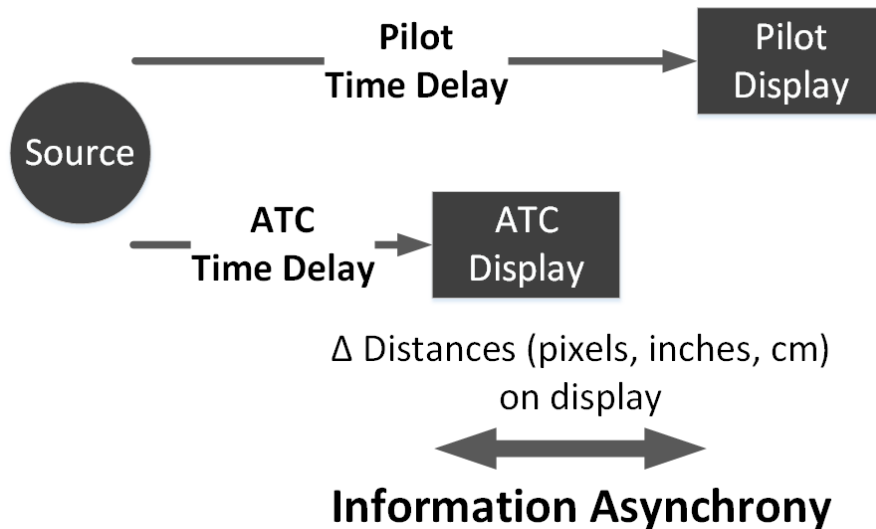


Figure 5-6: Difference in display distance as measurement to replace time delay

5.3.2.4 What about the Essence of the Study Environment being on the Web?

Finally, one interesting question was whether the essence of the study environment being on the web, particularly the simulator environment contributed to lack of observable effect of information asynchrony on pilot-controller communication. Specifically, the hypothesis was that the online simulation environment failed to produce the necessary condition for information asynchrony to occur, thus contributing to the result. If the hypothesis is true, there would be no point of addressing the previous limitation without switching to the traditional physical lab setting.

Evidence against this hypothesis includes the fact that participants were using strategies to mitigate the effect of information asynchrony as they would in real life. As well, participants indicated that representative effect of information asynchrony were in fact captured in the study including: 1) controllers not trusting the radar display due to sensing that pilot was seeing something on the navigation display not shown on ATC radar display, 2) confusion experienced by both pilots and controllers to why the other party gave certain instructions, and 3) controller's inability to provide effective control instructions to pilots. Representative comments are presented as below.

- *The pilot sensed something which I didn't see on radar, this cause me to not trust my radar.*

- *Possible confusion about why ATC are asking you to make a maneuver.*
- *ACA1 could identify visually if there was a threat or not, while I could only suppose and give information regarding UAS movement.*

Thus, the implication here is that future experiment design can still be based on online simulator environment delivered on the web. There is no reason, based on the above supports, to warrant the essence of the study environment being on the web as a study limitation.

5.4 Chapter Summary

Analysis was conducted on both the subjective participants' ratings and objective measurement of pilot-controller communication on whether there was a generally observable effect of information asynchrony on pilot-controller communication, as stated in Objective 4. The result of the data analysis was that there is no generally observable effect of information asynchrony on pilot-controller communication.

Factors that may have contributed to this result include participants' performance, where participants were using strategies to mitigate information asynchrony. As well, there was the limitation of visual out-the-window and audio cues (from radio chatter of other aircrafts) that may have limited the accuracy of decision-making. There were also the difficulties with simulator procedure in terms of difficulty to maintain a consistent simulator procedure due to different working and communication styles by professional participants of different training, experience and backgrounds. Finally, there were the limitations with measurement of information asynchrony, including the need for a more robust measurement of communication, and a more direct measurement of information asynchrony. For the latter, a suggested new measurement would be the difference in physical distance between display and 'actual' location of an object in light of information asynchrony.

Last but not least, it was encouraging that there was no evidence to support that the essence of the simulator environment being on the web was a study limitation in contributing to the lack of observable effect of information asynchrony. This can be supported by the fact that participants were using strategies to mitigate effect of information asynchrony during simulator session. Thus, this points to the simulator environment being successful in capturing representative effects of information asynchrony to real life.

Chapter 6

Lesson-Learned Critique of the Integrated Modular Platform

This chapter presents a lessons-learned critique on the Integrated Modular Platform after the case study demonstration in Chapter 4 and Chapter 5. The lessons-learned critique fulfills Objective 3 of this thesis. Lessons learned were identified in order to provide useful knowledge for future researchers looking to deliver similar research studies online in the future. The critique was not meant to be fully comprehensive covering all aspects of the Integrated Modular Platform. Instead, the critique focused on topics of interest within two areas most relevant to utilizing the Integrated Modular Platform to deliver an interactive, ATC-flight simulator study.

The chapter first presents the critique methodology (Section 6.1). Subsequent sections then present the details of the critique.

6.1 Critique Methodology

Based on Objective 3, the two areas that the critique focused on included: 1) participant's experience with an interactive, simulator-based research study delivered on the web, and 2) recruitment of subject-matter-experts. The following two sub-sections present details of analysis methodologies used in the critique. Specifically, Section 6.1.1 presents the statistical analysis used for quantitative data, and Section 6.1.2 presents the statistical analysis methodologies used for supporting qualitative data.

6.1.1 Analysis Methodology for Quantitative Data

Quantitative data here refers to categorical rating responses from the post-experiment surveys. Chi-square goodness of fit analysis was chosen due to the categorical (ordinal) nature of the data. The purpose was to look for any statistical difference of a significant result to a hypothesized result expected from the larger population of professional pilots and controllers (Preacher, 2001; Howell, 2013). The Freeman-Holton extension to Fischer's exact test²³ of independence (Freeman & Holton,

²³ The more typical chi-Square test is inappropriate due to at least 20% of the cells having an expected frequency less than 5.

1951) was used to look at how widespread participants' responses were among different demographic sub-groups in the sample population (Preacher, 2001; Howell, 2013). Professional background (professional pilot and controller) was used as the demographic group. Ratings from pilot and controller participants were categorized into two homogenous groups for analysis.

A special consideration was whether to use Yate's correction of continuity in the analysis with expected frequency of less than 5. Due to its tendency to overcorrect, and unsuitability to cases with a degree of freedom > 1 the recommendation to not use it was followed (Maxwell, 1976; Preacher, 2001).

Finally, to take into account the familywise error rate, a Bonferroni correction strategy was used. To preserve a 5% chance of Type 1 error rate in multiple hypothesis test of the same piece of data (two in the analysis), a corrected α value of 0.025 ($0.05 / 2$) was used (Hochberg, 1988).

6.1.2 Analysis Methodology for Qualitative Data

The qualitative data used as supporting data in the evaluation analysis included open-ended questions for keywords, suggestions and comments from participants. Here, the main analysis strategy used was coding analysis. Coding analysis, in the context of qualitative data collected from post-experiment questionnaires, referred to the act of categorizing participants' responses and draw connections and patterns between categories to identify themes (Packer, 2011). Specifically, the process involved separating responses by conceptual categories that were abstracted from terms used in the response. Then, the categories were integrated through identifying relationships between them to produce themes.

An example of this included the question to participants in post-experiment survey on what aspects of the effect of information asynchrony were representative to real life. Here, one participant provided the comment: *"The pilot sensed something which I didn't see on radar, this cause me to not trust my radar"*. This response was first assigned the conceptual category: *"loss of trust from display information discrepancy"*. Another participant gave the comment: *"Knowing that I'm working with lagging data, I have to project what a target is likely to do based upon past performance"*. This was being assigned with: *"absorbing lag from future prediction"*. Looking at the relationships of these two categories, they were integrated into: *"information discrepancy and its effect"*.

6.2 Results (1) - Participant's Experience with an Interactive, Simulator-based Research

Study Delivered on the Web

There were two focuses in the lessons-learned critic on participants' experience. The first focus sought to answer if the online ATC-flight simulator was representative of real world work practices (Section 6.2.1). The second focus looked at participants' experience with delivery of simulation environment (Section 6.2.2).

6.2.1 Were Real World Work Practices Elicited?

This first focus sought to answer the question of whether any representative or non-representative work practices and behaviours were brought out during the simulator session. Here, participants' responses, author's experience, and recorded transcripts were reviewed for the identification purpose. For clarification, the term "work practices" referred to standard actions, procedures, communications that would typically be occur in a given situation in ATC-flight operation. The term "behaviour" referred to the reactionary human behaviour in a given situation. Here, analysis of identified work practices and behaviours (Section 6.2.1.1), and discussion on any findings, implications and lessons-learned (Section 6.2.1.3) are presented below.

6.2.1.1 Identified Work Practices / Behaviours

This section presents the analysis of representative and non-representative work practices and behaviours identified from reviewing participants' responses. The responses were collected during the study from post-trial questionnaire as well as post experiment surveys. The practices and behaviours were categorized into three groups: 1) those specific to pilot tasks, 2) those specific to controller tasks, and 3) those specific to pilot-controller communication. Samples of post-trial questionnaire and the two post-experiment surveys can be found in Appendix B to Appendix F.

6.2.1.2 Practices / Behaviours Specific to Controller Tasks

There were two representative work practices and one representative work behaviour identified from participants' responses and author's experience as experimenter. First, from pilots' responses in post-trial questionnaire, pilot participants indicated that controllers were providing traffic information to them as expected, especially with traffic situations to unidentified objects such as UAS. A representative comment is presented below.

- *Situational Awareness – Just like in the real world, I rarely know the clearance of another aircraft. Are they climbing or descending, Will they stop climbing or descending. I often have no way of knowing unless the controller issues this information. Which they often do.*

A second representative work practice was identified as controllers projecting the next likely location of target information based on past performance, as well as allocating advanced time to plan ahead in an ongoing situation and providing more separation space. This practice was used by controllers to absorb asynchrony in the data as in real life (see Section 5.3.2.1). Representative comments are presented as below.

- *Knowing that I'm working with lagging data, I have to project what a target is likely to do based upon past performance.*
- *Use increased separation or insured separation - Rely on communication with the pilot (weather conditions, altitude reports) to improve the accuracy of my mental model.*

Controller participants also indicated that the unpredictability of air traffic caused their anxiety level to increase, particularly by the unpredictability of the UAS. Representative comments from the post-experiment surveys included:

- *Controller anxiety levels go up - Unknown is impossible to deal with.*

In terms of non-representative working practice, there was one identified from participants' responses from post-experiment surveys. This included working to validate and manage traffic with clustered traffic data on the screen without the ability to adjust the orientation of the data tags by zooming in on the screen. This was due to the lack of direct control of the participants between web and simulator PC, and the fact that such simulator function was not included due to time constraint and complexity of coding.

6.2.1.2.1 Practices / Behaviours Specific to Pilot Tasks

From participants' comments reviewed, there were two representative work practice and one behaviour identified. One representative working practice was the adherence to the traditional hierarchy of air traffic controller verses pilots during ATC-flight operation. This can be seen from the following representative comments where pilot participants commented on the outcome of

controller's instructions extensively, reflecting how the instructions were likened as commands to be followed unless situations warrant otherwise.

- *Controller clearly communicated conflicting traffic and his plan to have me vectored around them. The scenario felt like a total non-event, with regards to the traffic situation.*
- *ATC climbed me relative to traffic but, did not issue traffic advisory when unknown traffic was a factor.*

Another representative work behaviour was pilots' strategies to mitigate effect of information asynchrony. This included making judgements with the given control instructions from the controller, or request / proceed with best corrective actions for diversion from clearance. As well, this included the strategies used by controller participants as well in projecting best likely future location of the target.

- *Proceed as cleared by the control if safe to do so. If not deemed safe use the next best corrective action by either diverting from clearance to avoid collision*
- *Mental projection of the latest information to get a "best guess" of traffic location.*

Finally, in terms of representative behaviour that was brought out of pilot participants, the participants indicated the large amount of energy spent wondering about what the controller was planning (clearance of own aircraft or other aircrafts) or the surrounding traffic's behaviour (climb or descend). Participants indicated that this behaviour was representative of the real world, as seen in the following representative comments.

- *Not knowing what the controller is thinking or planning – This is representative of the real world. I expend a lot of energy wondering if the controller is planning to issue a clearance to avoid traffic.*
- *Situational Awareness – Just like in the real world, I rarely know the clearance of another aircraft. Are they climbing or descending, Will they stop climbing or descending. I often have no way of knowing unless the controller issues this information. Which they often do.*

6.2.1.2.2 Pilot-Controller Communication Practices

The communication practices utilized by the participants were deemed to be representative of real life. To illustrate this, an excerpt from the simulator transcripts and ATC-pilot transmission from

CYYZ Terminal (May 16, 2015 1638 EST) on LiveATC.net were chosen and compared with each other. The excerpt from the simulator transcripts were chosen to show full interaction between the experimenter, ATC and pilot participants. The excerpt from LiveATC.net was chosen from a full 45 min transcript that contained “Air Canada” call sign. Each individual phrase spoken by the same ATC / pilot side is compared side-by-side in Table 6-1. Note that ACA1 is pilot participant’s call sign, while ACA018 is role-played by the experimenter himself.

Table 6-1: Transcript comparison

Simulator Transcript	LiveATC.net
<p>ATC (to ACA1): Air Canada 1, maintain your present heading, turn yourself to localizer, descend to three thousand.</p> <p>Pilot (to ACA1): Alright set present heading, down to three thousand Air Canada 1...uhhh Sam set three thousand on the localizer please.</p> <p>Experimenter (to ACA1): Set three thousand.</p> <p>ATC (to ACA018): Air Canada 018, right turn heading one eight zero. Turn to intercept localizer.</p> <p>ACA018 (to ATC): One eight zero, Air Canada 018</p>	<p>ATC (to ACA126): Air Canada 126, two ten heading, intercept, cleared ILS approach 24R.</p> <p>ACA126 (to ATC): two ten to intercept, cleared ILS 24R, Air Canada 126</p> <p>ATC (to ACA164): Air Canada 164, now descend to eight thousand for 24R, altimeter three double O five.</p> <p>ACA164 (to ATC): K eight thousand, 24R, three double O five, Air Canada 164.</p>

The overall structure and content of the language were largely similar. For example, the phrases used in terms of instructions given to pilots and pilots read back for headings, altitude and intercept manoeuvring were largely similar. As well, the cadence of the communication was similar in speed, but was observed to be slightly slower in the simulator session.

However, there were also two aspects of the communication practice identified that were non-representative of real life. Controllers indicated in post-experiment surveys that having pilot participants call out to the experimenter to change aircraft trajectories, as occurred in some of the simulator sessions, clogged up the frequency at times. In real-life, this would not happen, as normally the pilots would have direct control of their aircraft. Any conversation about implementation would

occur solely within the cockpit without being broadcasted on pilot-controller channel. Representative comments are as follows.

- *In real life, I would not hear ACA1's captain give his co-pilot navigation instructions on the frequency. This clogged a bit the frequency for me to control other aircraft.*
- *[Pilot] Inability to interact with the controls - On a number of instances during the trials, I would have intervened on the controls...for one reason or another.*

A second non-representative aspect of the pilot-controller communication practice was the absence of normal captain-first officer communication due to the fact that pilot participant did not have a co-pilot participant to communicate to. The experimenter controlling the simulator did not count as a co-pilot, as pilot participants would not discuss any decision-making matter with him the experimenter, but only issuing instructions to change own aircraft performance. This also caused role confusion at times. Normally, the pilot would communicate with a co-pilot for discussion traffic situation for more informed decision-making. A representative comment is presented as below.

- *Confusion over role - In my real work environment, I communicate with the other pilot. We both watch and analyze what we are seeing, which makes it easier to make informed decisions.*

6.2.1.3 Discussion

The results above suggest the online simulator environment has high potential of mimicking real-life ATC-flight operation. This can be supported by two observations. The first observation was that the environment appeared realistic enough to allow participants to use representative practices. This can be seen in the representative communication practices being used by the participants. As well, this can be also seen in the controller-specific behaviour of providing traffic information such as location, speed, altitude and current manoeuvre of aircraft, and pilot-specific behaviour of adherence of the traditional hierarchy of air traffic controller verses pilots during ATC-flight operation.

The second observation was how factors causing the non-representative practices and behaviours were largely due to limitations with the *as implemented* online simulator technology and experiment setup. The significance of this was that the limitations were not of inherit weaknesses associated with online environment. Rather, the limitations can be solved through emerging online web technologies that can be incorporated into the Integrated Modular Platform (i.e. provide direct

input capability to participants), as well as better experiment setup (i.e. add an additional pilot participant to be a co-pilot).

6.2.2 Experience with Delivery of the Simulator Environment on the Web

This is the second focus of the critique, with three topics of interests for evaluation in terms of participants' experience with the delivery of the simulator environment on the web. The first two topics looked at participants' quantitative ratings and qualitative descriptions of their experience with online communication and video-only simulator implementation. For the third topic, the evaluation looked at what participants felt were important characteristic elements required for a successful delivery of this study online. The three topics are presented in the following sub-sections.

6.2.2.1 Participants Experience with Online Communication Implementation

6.2.2.1.1 Participants Rating Responses

The Likert-scale rating response of whether pilot and controller participants feel comfortable with the online communication implementation is presented in Figure 6-1. The figure is collapsed from a 7-point rating to 3-point rating of "disagree", "neither agree nor disagree" and "agree". The purpose was for testing whether the distribution of ratings could have occurred by chance if there wasn't such strong agreement in the complete population of pilots and controllers. The figure also showed the one participant who did not participate in the survey. The 7-point rating responses can be seen in Figure I-1 and Figure I-2 in Appendix I.

Chi-square goodness of fit was used to test if the results could be used to reject the hypothesis that one-third of the complete population would fall into each response category²⁴.

²⁴ E.g. one third will disagree, and one third will neither disagree nor agree.

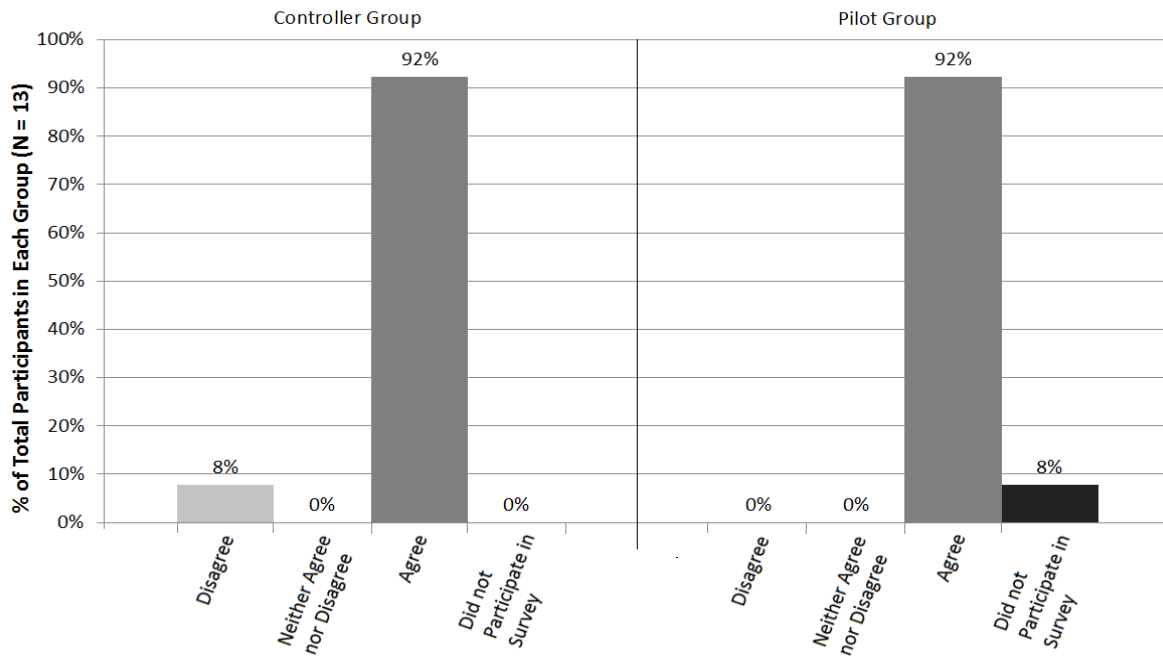


Figure 6-1: Pilot and controller participants’ collapsed 3-point self-assessed rating on whether participants feel comfortable with the online communication implementation

N = 12 was used for the chi-square calculation for the pilot group as one participant did not participate in the survey. The result showed that the ratings were significantly different across the three categories for both professional backgrounds, controllers: $\chi^2 = (2, N=13) = 20.462, p < 0.001$ and pilots: $\chi^2 = (2, N=12) = 24.0, p < 0.001$.

6.2.2.1.2 Participants’ Suggestions for Improving Participants’ Comfort Level with the Online Communication Implementation

Coding analysis was conducted on participants’ comments on suggestions for how future participants can be more comfortable with the online communication implementation. The top three themes are presented in Table 6-2. A description for each theme used in this table can be found in Table J-1 in Appendix J. The “%” represents percentage of total participants (N = 26), which included the single participant who did not participate in the survey.

Table 6-2: Participant suggestions to make future participants feel more comfortable with the online communication implementation

Theme	%	Representative Comments
Comments indicating no improvements needed	23%	<ul style="list-style-type: none"> • No complaints :) • Overall satisfied with the process
Better communication etiquette	8%	<ul style="list-style-type: none"> • Not all pilots or controllers in the world are English native...be patient with them and speak slowly, when necessary. :-). • Just wish there was a way not have all the mics be hot all the time.
More familiar with online communication process and technology beforehand	8%	<ul style="list-style-type: none"> • Setting up a test session for the communication might have been nice. I was not familiar with Google Hangout and was unsure how to participate. • Communication was good, but I should have been told earlier in the process to familiarize myself with new technologies like Skype and Google chrome.
Other	27%	<ul style="list-style-type: none"> • Direct communication sometimes before the study • Security is an issue these days but I was comfortable it was Waterloo I was speaking with.
Did not answer ²⁵	35%	-

6.2.2.1.3 Discussion

The coding analysis suggested that a vast majority of participants felt comfortable with the online communication implementation. This can be supported by how 23% of total participants indicated in their comments that they had no suggestions for improvement, as compared to other themes for improvements.

²⁵ Participants did not answer the question (no comments put down). This also included the single participant who did not participate in the survey.

However, an interesting observation was how, while only four participants contributed to the remaining two top suggestions for improvement, the two issues that they brought out were observed by the author to have more negative impact to participants' experience during simulator session, than what the representative comments conveyed. For example, in terms better communication management, the author could sense the annoyance from some of the participants about hot mics during post-experiment survey from participants' communication behaviours. Similarly, the unfamiliarity with online communication technology beforehand was observed to have caused the delays in studies, at times by more than 30 minutes as author assisted participants with troubleshooting.

Thus, future researchers should attempt to improve communication etiquette, as they can be quite detrimental to participants' experience. To address the unfamiliarity problem, as future researchers should look into providing a video briefing on online communication setup and settings. This would allow participants to familiarize with the online communication setup through live demonstration of setup and setting manipulations.

6.2.2.2 Participants Experience with the Video-Only ATC-Flight Simulator Implementation

6.2.2.2.1 Participants' Rating Responses

The self-assessed rating of whether participants felt comfortable with the video-only simulator implementation is presented in Figure 6-2. The figure is collapsed from a 7-point rating to 3-point rating of "disagree", "neither agree nor disagree" and "agree". The purpose was for testing whether the distribution of ratings could have occurred by chance if there was not such strong agreement in the complete population of pilots and controllers. The figure also showed the one participant who did not participate in the survey. The 7-point rating response can be seen in Figure I-3 and Figure I-4 in Appendix I.

Chi-square goodness of fit was used to test if the results could be used to reject the hypothesis that one-third of the complete population would fall into each response category²⁶.

²⁶ E.g. one third will disagree, and one third will neither disagree nor agree.

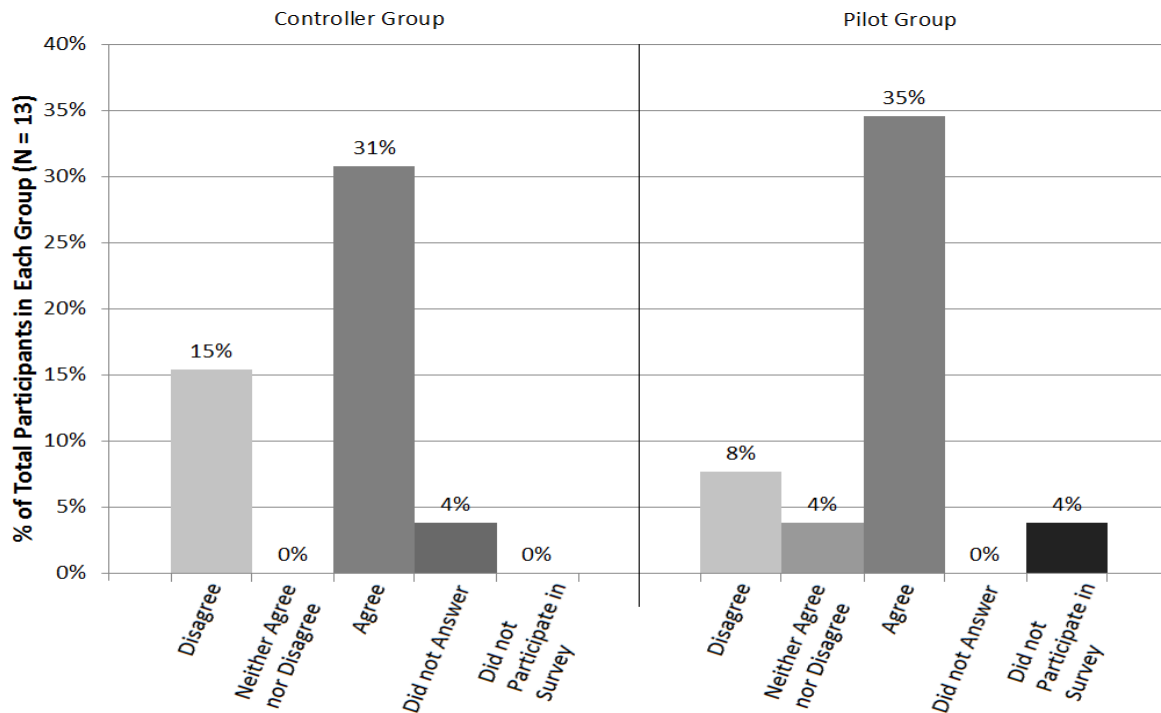


Figure 6-2: Pilot and controller participants' collapsed 3-point self-assessed rating on whether participants feel comfortable with the video-only simulator implementation

N = 12 was used for the chi-square calculation for both pilot and controller group as one participant in each group did not answer / participate in the survey, respectively. The result showed that the ratings were significantly different for both professional backgrounds, controllers: $\chi^2 = (2, N=12) = 8, p = 0.018$ and pilot: $\chi^2 = (2, N=12) = 9.5, p = 0.0086$.

6.2.2.2.2 Participants' Suggestions for Improving Participants' Comfort Level with the Video-Only Simulator Implementation

Coding analysis was conducted on participants' comments on suggestions for how future participants can be more comfortable with the video-only simulator implementation. The top four themes from the coding analysis are presented in Table 6-3. Description for each theme used in this table can be found in Table J-2 in Appendix J. The "%" represents percentage of total participants (N = 26), which included the single participant who did not participate in the survey.

Table 6-3: Participant suggestions to make future participants feel more comfortable with the video-only simulator implementation

Theme	%	Representative Comments
Provide direct input control of simulator for participants	50%	<ul style="list-style-type: none"> • Have an interactive display, with clicking and tag-moving available. • Have some kind of controls to fly the plane (heading, altitude, speed).
Improve on display presentation issues	46%	<ul style="list-style-type: none"> • I would rather have more cockpit displays and a TCAS. • Too much info on display and it was very distracting.
More comprehensive training for the video-only simulator environment	12%	<ul style="list-style-type: none"> • Emphasizes pre-preparation - there was a lot of material to absorb. • A training program for the participant to play with at home would be a real advantage in that it would allow a much more comfortable level to start.
Comments indicating no improvements needed	8%	<ul style="list-style-type: none"> • I thought the presentation was well-thought out. I was comfortable.
Other	46%	<ul style="list-style-type: none"> • Have other communicators to work for other potential aircraft in the simulator. • The session should be divided into two shorter sessions to allow the training to be settled.
Did not answer ²⁷	8%	-

6.2.2.2.3 Discussion

The results suggest that participants had more negative experience with the video-only simulator implementation than the online communication implementation. The lack of direct control over their displays was clearly the top issue for participants. This was significant as this issue was also the culprit of a majority of the non-representative working practices as mentioned in Section 6.2.1.3, as well as possible constraint that contributed to the lack of observable effect of information

²⁷ Participants did not answer the question (no comments put down). This also included the single participant who did not participate in the survey.

asynchrony, as discussed in Section 5.3.2. Future researchers should make this issue as the top priority as it would dramatically improve participants' experience in terms of better realism, more effective decision-making affecting the accuracy of information asynchrony measurement, and eliminating the aforementioned non-representative behaviours.

It was also interesting to see that some participants expressed the desire for more simplified display for less distraction, while others expressed for more display details. This was as expected, as different participants had different experience and training. Thus, the amount of details was highly dependent on participant's professional experience and background. While the issue was not related to any inherent technical limitation associated with the video-only simulator, this also pointed to the trend that professional participants highly valued realism in an ATC-flight simulator study, with simulator presentation representing a big role in realism.

Finally, in terms of the need for more comprehensive training, this suggested that participants felt underprepared with the limited time and material given for preparation prior to a simulator session. This was understandable, given the extensive training that professional pilots and controllers would normally receive prior to operating in a new aircraft or airspace environment. For comparison, typical air traffic controller trainees in Canada would go through class and on-the-job training lasting about 15 to 30 months (Transportation Safety Board of Canada, 2015), compared to a few days to review materials for this studies in light of other commitment such as work. Future researchers should look to match pre-simulator preparation as closely as they can in terms of more time and materials provided to professional participants.

6.3 Results (2) - Subject-Matter-Expert Recruitment

This section presents the lessons-learnt critique on the second critique area. There were two topics of interests for second evaluation area, including 1) learning more about participants' experience with the recruitment process as implemented in the study (Section 6.3.1), and 2) looking at how effective the scheduling process was pairing and scheduling qualified SMEs to participate in the simulator session (Section 6.3.2).

6.3.1 Participants' Experience with the Online Recruitment Process

6.3.1.1 Participants Rating Response

The self-assessed rating of whether participants feel comfortable with the online recruitment implementation is presented in Figure 6-3. The figure is collapsed from a 7-point rating to 3-point rating of “disagree”, “neither agree nor disagree” and “agree”. The purpose was for testing whether the distribution of ratings could have occurred by chance if the responses would be equally distributed in each category if the complete population of pilots and controllers completed the experiment. The figure also shows the one participant who did not participate in the survey. The 7-point rating response can be seen in Figure I-5 and Figure I-6 in Appendix I.

Chi-square goodness of fit was used to test if the results could be used to reject the hypothesis that one-third of the complete population would fall into each response category (e.g. that one third will disagree, and one third will neither disagree nor agree).

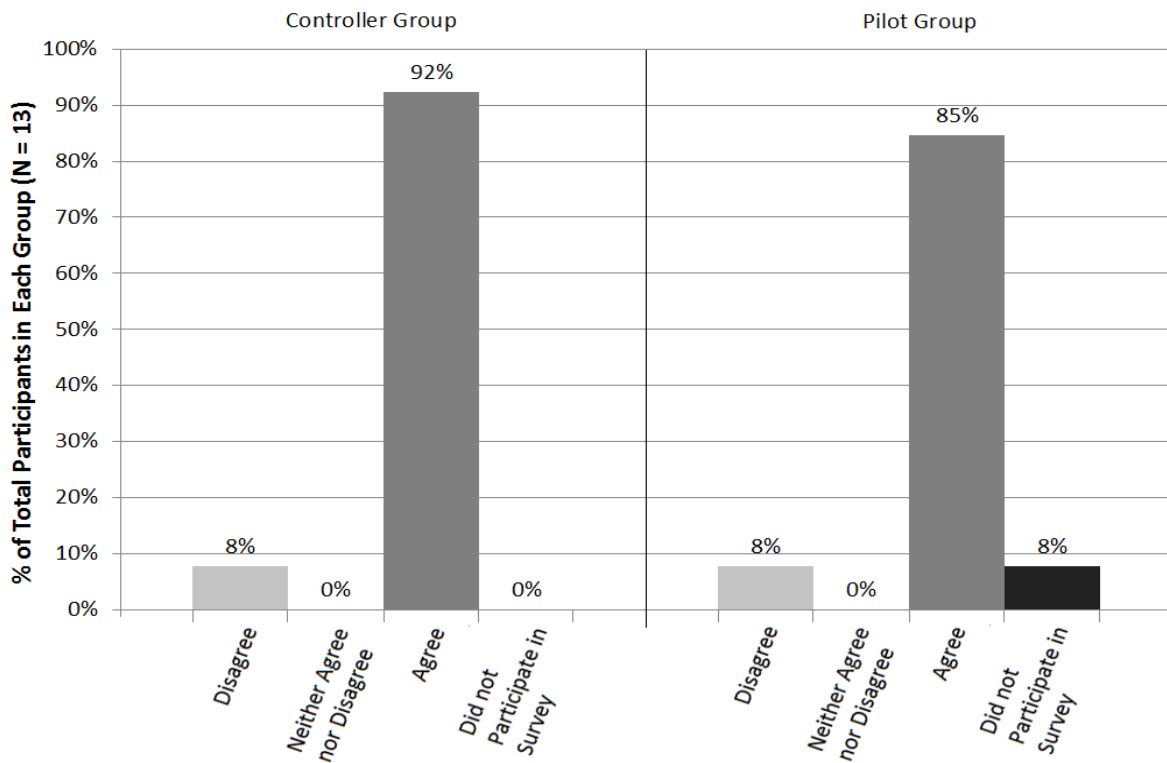


Figure 6-3: Pilot and controller participants' collapsed 3-point self-assessed rating on whether participants feel comfortable with the online recruitment implementation

N = 12 was used for the chi-square calculation for the pilot group as one participant did not participate in the survey. The result showed that the ratings were significantly different for both professional backgrounds, controllers: $\chi^2 = (2, N=13) = 20.462, p < 0.001$, and pilots: $\chi^2 = (2, N=12) = 18.5, p < 0.001$, respectively. As well, from Figure 6-3, it is quite obvious that there is a balanced spread of professional background among observed rating frequencies for “disagree”, “neither agree nor disagree” and “agree”. Here, each controller and pilot group represents the controller and pilot background, respectively.

6.3.1.2 Participants’ Suggestions for Improving Participants’ Comfort Level with the Online Recruitment process

Coding analysis was conducted on participants’ comments on suggestions for how future participants can be more comfortable with the online recruitment process. The top three themes from the coding analysis are presented in Table 6-4. Actual representative participants’ comments were included. Description for each theme used can be found in Table J-3 in Appendix J. The “%” represents percentage of total participants (N = 26), which included the single participant who did not participate in the survey.

Table 6-4: Participant suggestions to make future participants feel more comfortable with the online recruitment process

Theme	%	Representative Comments
More comprehensive briefing and preparation for simulator session	50%	<ul style="list-style-type: none"> • Better understanding of the Survey requirements. • Honestly, I wasn't sure what you were studying. Maybe a better explanation would help so that people could better understand the study. • Screenshot of what they might expect.
Comments indicating no improvements needed	27%	<ul style="list-style-type: none"> • None, happy with the process.
Trust issue	12%	<ul style="list-style-type: none"> • Probably the biggest thing to make people more comfortable is for them to have friends who have had positive experiences. • Helps to have a reference from Professor. • Whenever possible, recruit directly through a university or some other entity that is recognized by the participants.
Other	38%	<ul style="list-style-type: none"> • The recruitment of two participants is hard to co-ordinate, more time is needed to secure common available times. • Offer to share the study results to participants.
Did not answer ²⁸	23%	-

6.3.1.3 Discussion

From the rating responses, a vast majority of the professional participants felt comfortable with being recruited for the study through the online recruitment process. This can be seen from how participants with no suggestions and who were simply satisfied with the implementation represented the second biggest portion of participants as compared to other “suggestion themes”.

²⁸ This also included the single participant who did not participate in the survey.

This also suggested that the overall online recruitment process as implemented was successful in terms of providing a positive experience for SMEs to self-register for the study.

Furthermore, it was interesting to see how the suggestion for more comprehensive briefing and preparation was the top theme. This was also the case with participants' opinion on what important characteristic elements that would be required for a successful deliver of an ATC-flight simulator study on the web. Again, this was due to discrepancy between the limited time and material provided to participants verses the large amount of time and materials they would normally have for real life training. As well, this pointed to the aforementioned drawback of online study of the increased risk of participants misunderstanding information due to the physical absence of the moderator during the recruitment session.

This drawback can also be supported by some of the comments revealing participants' wish to verbally communicate directly with the research team / experimenter during recruitment to clarify issues. This was due to the self-serving nature of the online recruitment, where participants had to read the documents themselves and email the moderator of any questions they may have. Thus, they may have felt that this process was more cumbersome than simply reading the documents in a physical lab with the moderator physically present to answer any questions on spot. To mitigate this in future studies, future researchers should state clearly in the information letter to encourage participants to book online conference session utilizing the online communication module with the experimenter for verbal clarification and explanation of any issues and uncertainty. This should be done in addition to just providing an email contact and phone number for the participants to reach the experimenter.

6.3.2 Effectiveness of the Online Scheduling Process Implementation for Subject-Matter-Experts

The second topic of interest was the scheduling process of SME for the simulator session. Specifically, this topic seek to investigate whether the scheduling process involving self-served online scheduler and then follow-up emails was effective in achieving the pairing and coordination for a simulator session date and time. Here, a review on implementation (Section 6.3.2.1), evaluation of the implementation according to the outcome of the scheduling process (Section 6.3.2.2), and discussions on any findings from the analysis (Section 6.3.2.3) are presented.

6.3.2.1 Implementation

The scheduling process implementation involved pairing a professional pilot to a controller and coordinate for a common date and time for the simulator session. This involved the use of online scheduler module by participants themselves first to indicate available date and time, then with follow-up emails from the moderator for further coordination as seen necessary.

As a review, the online scheduler module SuperSAAS was used as the third-party online technology for the online schedule module. The online scheduler was meant to be a self-served scheduler for participants to indicate available dates right after completing the demographic questionnaire. The scheduler was customized to have two open slots per two hour on a Monday to Sunday schedule, with one slot for controller and one for pilot. It was assumed that a pilot or a controller would sign up for a slot first. Then, a counterpart would likely sign up to the corresponding spot. The purpose of the self-served online scheduler was such that minimum intervention from the researcher would be necessary to assist with scheduling, as much of the scheduling and pairing was expected to be done by participants themselves. After indicating available dates and time on the scheduler, the experimenter would then confirm common dates and group through follow-up email, and work out any scheduling conflicts that may arise.

6.3.2.2 Results Analysis

From author's observation, the online scheduler was rarely used by the participants to schedule a simulator session slot. Instead, participants relied on email exchange with the moderator to work out a date and time. For example, out of the 26 participants who participated in the simulator session, only five participants used the scheduler to indicate available date and time. The rest opted not to use the scheduler but instead wait to be contacted by the author within 48 hours for more details. Furthermore, throughout the recruitment process, none of the pairs were formed solely through the online scheduler, but through email contacts working with individual participants to find matching suitable time and dates. Further analysis showed that the reason for lack of usage of the scheduler and failure for pairing was not a technical issue with the scheduler but more of a usability issue in terms of wrong assumption of how participants would actually use the scheduler. Three possible explanations can be drawn as to this usability behaviour from the participants, with first and last explanation being most probable.

First, participants may still have been uncertain about future available dates at the time of the registration process, thus was hesitant to select a slot using the online scheduler. However, participants were unable to return to reserve a slot at a later date as the self-served recruitment process can only be done once prior to screening.

Second, the instructions on how to use the online scheduler may be confusing to follow, thus participant simply did not want to use the scheduler. However, this was not brought up in participants' comments as suggestion for improvement with the online recruitment process, thus cannot be verified and was not probable.

Third, different working schedule patterns between professional pilots and controllers may have contributed to the difficulty for a controller and a pilot to match preferred date and time. This difficulty may be aggravated by the small participant sample size of 26 participants who indicated their available dates that worked out, as well as very slow sign-up rate at about one potential participant signing up per week. From the author's experience interacting with the participants for scheduling, professional pilots and controllers sometimes would not reply for a week at a time due to flying schedule.

6.3.2.3 Discussion

From the result analysis, the online scheduler implementation was not effective in forming pilot-controller group and schedule for simulator session due to usability. Instead, a pure follow-up email strategy was effective in both schedule and pair participants for a common time in mitigating the usability issue. Here, participants were directly contacted by the experimenter regardless if he or she indicated a date and time on the online scheduler. Further scheduling and pairing was all done through email interactions. This alternative methodology was found to be suitable for environment with expected small participant sample size and slow sign-up rate by potential participants, and would be recommended by the author as such.

However, in case of a large sample size and high sign-up rate such as multiple participants per day, the use of a self-served online scheduler module may help to offload workload for the experimenter. This would allow participants to manage available dates at their own time without as much interaction and coordination between experimenter and participants. To avoid the same usability issue, future researchers should provide access link to the online scheduling webpage with

the embedded online scheduler through the follow-up email, instead of having participants accessing it right after answering demographic questionnaire. This would allow participants to have the flexibility and more time to think through their available dates, as well as return to the online scheduler for any modifications.

Finally, the importance of flexibility on the part of the experimenter must still be emphasized, as participants have rights to utilize any channel to contact experimenter about available dates or changes in schedule. It is up to the researchers to use the most effective methodology to tailor to specific scheduling need in different situation.

6.4 Chapter Summary

Two major critique areas were presented in this chapter in fulfilling Objective 3 of this thesis. The areas included critique on 1) participants experience with the interactive, simulator-based research study delivered on the web, as well as 2) the recruitment process of SMEs.

Findings from analyzing participants experience in the first critique area showed that a majority of professional participants generally had a positive experience participating in the interactive ATC-flight simulator delivered on the web. As well, the online simulation environment successfully demonstrated its capability to represent real world work practices, with potential for improving environment realism through emerging third-party web technologies. The findings here can serve as confidence for future researchers wishing to utilize the Integrated Modular Platform for similar studies. However, limitation to the simulator implementation in terms of providing direct input to participants should be addressed as top priority in the future work due to its negative effect on representative working practices.

In terms of SME recruitment process, a vast majority of participants had positive experience going through the recruitment process as implemented. Main findings include participants' wish for more comprehensive briefing and training to be implemented in the recruitment process. This included as much training materials as possible to help participants be familiarized with technologies and procedures involved in the online experiment prior to the simulator session. Particularly, future researchers should provide more opportunities for participants to speak to the researchers / experimenters on the web to clarify issues anytime leading up to the date of simulator session. This may also improve participants' trust with the legitimacy of the research institution and researcher.

Finally, one weakness in the online recruitment process for SME was the generated online scheduler webpage being ineffective in forming pilot-controller group and schedule for simulator session. This was due to usability issue in terms of wrong assumption of how participants would actually use the scheduler. Participant may be hesitant to indicate a slot right away due to uncertainty with an available date for simulator session, but cannot return at later date to indicate a slot due to implementation limitation. As well, it was difficult for a controller and a pilot to match preferred date and time due to different working schedule and small sample size. Future researchers are suggested to simply ask participants directly in follow-up email after online recruitment process if sample size is small. If the sample size is big, researchers can include the link to the online scheduler web page in the follow-up email, allowing participants to have more flexibility in managing available dates for simulator session.

Chapter 7

Conclusions and Future Work

The availability of the internet provides researchers advantages in delivering experiments to subject-matter-experts, such as reduced cost, 24-hour availability, and the elimination of travelling distances for participants to a physical lab. However, limitations with existing web platforms has meant there has been a lack of studies requiring multiple participant interaction, complex task environments and high research control being delivered on the web.

Motivated by the existing limitations, this thesis proposed an Integrated Modular Platform tailored to deliver complex research studies on the web, as well as being user-friendly to researchers with limited programming skills. The prototype platform was created and evaluated through a case study approach, with the delivery of a follow-up study on information asynchrony as representative study of an interactive ATC-flight simulator study.

This chapter presents the main research findings, as well as future work to carry forward. These are presented in three sections. The first section reviews the objectives outlined in this thesis and provides a summary of how each was achieved, as well as the research findings resulting from the objectives. The second section presents the contribution of the research findings to the larger research community, particularly to researchers who wish to consider delivering a similar complex research studies on the web. Finally, the last section proposes future work.

7.1 Research Objectives and Key Findings

This section presents a summary of how the five objectives of the thesis were achieved, and any contributions or resulting key findings from each objective. The objectives were mentioned in Section 1.3, and are restated here as the following along with summary presentation.

Objective 1: Develop a web-based platform suitable for delivering an interactive aviation complex research study online to SMEs.

This objective was achieved through first identifying capabilities needed for an interactive ATC-flight simulator study, then specifying design requirements and formulating Platform Model. Then, the web application of the prototype platform was created through using ASP.Net framework

language with HTML, CSS, JavaScript and server scripting. These were presented in Chapter 3. The creation of the platform enabled subsequent objectives to be achieved. As well, the creation of the Integrated Modular Platform showed how distributed systems design approach can be quite useful with a platform-module system offering highly flexibility and reusability for different research studies, while realizing representative experiment workflow of a complex research study. However, there was still a need in the future to implement a user-friendly interface to create workflow in order that non-programming researchers can customize modules to generate desired experiment webpages without having to modify codes by hand.

Objective 2: Demonstrate the integration of third-party web services required for a complex human factors research study into the web-based platform.

This objective was fulfilled in Chapter 3 by demonstrating how third-party online services can be embedded in certain platform modules through HTML embed codes, thus integrating the technologies from these online services into the Integrated Modular Platform as one package. Examples include third-party online services such as FluidSurveys™ and Google Hangout used for Document Delivery Module and Online Conference Setup Module, respectively. Besides third-party online services, there were also custom-made technologies built into other modules due to lack of third-party online services offering similar technologies. An example of this was custom-made webRTC technology used for the Simulator Delivery Module to deliver video-only simulators on the web. Achieving this objective pointed to a maturing internet technology trend, where researchers using the platform can integrate many existing and emerging online technologies. This allowed for a continuously-upgradable platform system that can meet emerging complex research study needs.

Objective 3: Identify insights, implications and lessons-learned for online complex experiment delivery from a representative case study.

The objective was achieved through first a case study demonstration, then lessons-learned critique on the Integrated Modular Platform. The first part was the use of a case study approach with a follow-up study on information asynchrony. The experiment designs, and recruitment of pilot and controllers as subject-matter-experts were successfully realized through using the Integrated Modular Platform.

The second part included lessons-learned critique on the platform on two areas of participants experience with an interactive, simulator-based research study on the web, as well as the recruitment process of SMEs. The overall message was that the Integrated Modular Platform was successful in delivering an interactive ATC-flight simulator studies on the web to professional pilots and controllers. Particularly, the online simulation environment delivered through the use of Integrated Modular Platform successfully demonstrated its capability to represent real world work practices, with potential for improving environment realism through emerging third-party web technologies. However, a priority need in the future is to include the ability for participants to directly manipulate simulator input through the web browser instead of through voice commands. This should allow representative working practice to be brought out of professional participants such as professional pilots and controllers in future ATC-flight simulation studies.

Furthermore, the recruitment of SME was generally successful in terms of providing positive experience for participants to be recruited for the study. This can be supported from vast majority of professional participants indicating they had positive experience. However, over half of participants suggested to provide more comprehensive briefing and training implementation for the simulator session in the future during the recruitment phase. In addition to providing as much pre-study material such as video-demonstration for simulator procedure and familiarization with technologies involved, participants wished to talk to researchers earlier on. This highlighted the flexibility of the Integrated Modular Platform in providing such needs through the Online Conference Setup Module.

Objective 4: Identify any observable effect of information asynchrony on pilot-controller communication applied to non-cooperative surveillance data.

Objective 4 was achieved through the delivery of the case study and analysis on participants' rating responses to questions in post-trial questionnaire, as well as objective measurement of recorded pilot-controller communication from each simulator trial. The main finding was that the effect of information asynchrony on pilot-controller communication was generally not observable, but the effect was present and successfully captured by the online simulator environment.

Factors that may have contributed to this findings include participants using representative strategies to mitigate asynchrony. This also included limitations aspect of the simulator affecting the accuracy of decision-making including limited environmental cues, single pilot operation, unfamiliarity of simulator environment, and lack of direct participant control of the simulator.

However, these limitations with the simulator can be improved with emerging technologies. Coupled with the fact that online simulator environments captured representative effect of information asynchrony, this suggested that online environment itself was not a factor as a study limitation influencing such result. Other study limitations included the difficulties of maintaining consistent simulator procedure due to different working practices and communication styles from participants' diverse backgrounds, experience and trainings. Finally, there was the need for more robust measurement of communication, as well as more affecting measurement for information asynchrony, such as the difference of physical distance between display and 'actual' location, instead of time delay.

7.2 Research Contribution

The contribution of this thesis lies in two major areas. The first research area was in regards to advancing online research methodology on the web, while the second research area was in the follow-up pursuit of investigating the human factor challenge with information asynchrony. These concern the larger research community as well as aviation community.

For the first area, this thesis made a significant contribution to the larger research community in developing a novel web platform with the successfully demonstrated capability to deliver complex research studies on the web. These studies can be represented by an interactive ATC-flight simulator study requiring multi-participant interaction, complex task environments and high degree of research control over participant's progress, selection and data collection process. The Integrated Modular Platform not only successfully delivered this type of studies online, but also promised great potential for high reusability and expandability for other simulator and non-simulator studies. This also included simple studies delivered by current existing web platform. This potential would come from its ability to integrate existing and future third-party online services for their technologies. As well, the modular design of the platform would provide future researchers with limited programming skills user-friendly customization for different experiment needs without having to modify codes. However, the proposed Workflow Configuration User Interface would need to be implemented first for the platform to reach the full potential. Hopefully, this advancement of the online research methodology can help open up more opportunities for other researchers in human factors, aviation or other research fields to deliver a more variety of complex research studies on the web.

As for the second research area, the thesis contributed in terms of providing valuable insights and challenges into the working practices and behaviours of professional participants in light of

information asynchrony, as well as study design. For example, the use of online methodology to deliver a dynamic ATC-flight simulator environment was promising as it captured representative effects of information asynchrony, bringing out representative working practices and behaviours from professional participants to a real-life ATC-flight operation. This signifies that this type of study does not always need to always be conducted in a physical lab environment, thus increasing the potential to recruit professional participants internationally. As well, the study presented further interesting challenges for more robust and effective characterization and measurement of information asynchrony and its effect on communication. There was a need also for more effective study design for more effective balancing between realism and consistency of simulator procedures when dealing with professional participants with different experiences and backgrounds. These would translate to future research challenges to further investigate the current findings with no general effect of information asynchrony on pilot-controller communication.

7.3 Future Work

Future work carrying forward consists of four areas. These include: 1) new methodology for characterizing and measuring information asynchrony and its effect on communication, 2) addressing technical limitations of online simulator environment, 3) bringing the platform to full potential in terms of usability for non-programming researchers, and 4) further evaluation of the Integrated Modular Platform with different types of studies.

For the first area, future researchers should look into adopting physical distances on display instead of time delays. This would allow a characterization of information asynchrony with more direct effect to pilot-controller decision-making and mitigation, allowing for more accurate measurement. Similarly, limitations with current communication measurements with events would need to be further researched for a more robust and formal measurement than simply six events used. Please refer to Figure 5-6 for the pictorial expression of this new characterization.

For the second area, future researchers should look to provide direct participants' control capability to the platform. The author would suggest the use of an online remote desktop for its ability to control a PC desktop from a web browser. One example can be the Google's Chrome Remote

Desktop™ (Google, 2015)²⁹. This would provide a seamless integration to the current platform which has the requirement for Chrome browser for its webRTC technology with the simulator delivery module. The author would recommend the use of the technology as built-in in the simulator delivery module along with the webRTC, since the participants would need to both see the simulator video-feed and control the simulator all on the simulator room page.

For the third research area, the Workflow Configuration User Interface (detailed in Section 3.3.1.1), would need to be implemented in order to fully allow researchers with limited programming skills to use the platform without the need to modify codes. This may require a developer to reformat the codes in order to implement the front-ends and back-end logics for the interface to function properly. A significant amount of research and development time would be expected for this, due to the current code structure being primarily hardcoded than dynamic. As well, more research would be needed to look into technical details of how the Workflow Configuration User Interface can be implemented as a web-page and interfacing with the modules on the internet. Furthermore, future work should also include eliminating the need to copy-paste HTML embed code into a text-box for third-party online services, but instead select different options of the services from a drop-down box. Finally, future work should include the ability to save “module configuration options” such that researchers can reuse different module configurations without have to re-specify for different experimental and professional needs.

Finally for the fourth research area, there is a need to further validate the practicality of the Integrated Modular Platform in delivering simulator and non-simulator-type studies. Simulator-type studies can include driving or surgery simulations. Non-simulator-type can include survey, interview-based, or telemetry-type studies. Future validations should include looking at whether the modules are capable of being configured for the aforementioned studies online by a non-programming researcher, with the implementation of the Workflow Configuration User Interface. As well, future validation should include further examining the recruitment implementation of the Integrated Modular Platform, with recruitment of SMEs in different professional field. The suggested online scheduling method should also be further tested in such validation for robustness.

²⁹ <https://chrome.google.com/webstore/detail/chrome-remote-desktop/gbchcmhahfdphkhhkmpfmihenigmpp?hl=en>

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Appendix A

Demographics Questionnaire

Instruction

This very short survey will help us to better pair you to a pilot / controller participant for the simulator session. Please answer all questions as best as you could. Please finish the survey at one go as you cannot save this survey. You will need to submit the survey first before you can proceed to the next page.

Please enter your participant ID

1. Gender

- Male
- Female
- Prefer not to respond

2. Age

- 20-30
- 31-40
- 41-50
- 51-60
- 61-70
- 71-80

3. My professional background includes:

Choose all that applies.

- Pilot (CPL)
- Pilot (ATPL)
- Pilot (PPL)
- Pilot (Military)

- Controller (Terminal)
- Controller (Tower)
- Controller (High enroute)
- Controller (Low enroute)
- Controller (Oceanic)

3a. What is your most recent occupation?

Ex. Work at Major US Airlines, TRACON at a major airport, SAR Pilot, etc.

3b. Which role would you like to perform in the simulator session?

- Pilot
- Controller

(Participant answered question 4 and 5 below if indicated CPL \ ATPL and any controller background)

4. I have worked as my professional background for:

	Less than 5 years	6-10 years	11-15 years	16-20 years	more than 20 years
Pilot	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Controller	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

5. My current status to my professional background can be best described as:

	Active	Retired
Pilot	<input type="radio"/>	<input type="radio"/>
Controller	<input type="radio"/>	<input type="radio"/>

(Participant answered question 4 and 5 below if only indicated controller background)

4. I have worked as professional controller for:

- Less than 5 years
- 6-10 years
- 11-15 years

- 16-20 years
- More than 20 years

5. My current status to my professional background can be best described as:

- Active controller
- Retired controller

(Participant answered question 4 and 5 below if only indicated CPL / ATPL)

4. I have worked as professional pilot for:

- Less than 5 years
- 6-10 years
- 11-15 years
- 16-20 years
- More than 20 years

5. My current status to my professional background can be best described as:

- Active pilot
- Retired pilot

6. Which country have you spent the most time based in working as you profession?

7. Have you participated in any experiment on the web prior to this experiment?

- Yes
- No

7a. If yes, how many experiments on the web have you participated in prior to this experiment?

- 1 to 3
- 4 to 6
- 7 to 9
- more than 9

7b. Please give some examples of experiments on the web you have participated in.

7c. Is your previous experience with participating in experiments on the web generally been positive or negative?

- Positive
- Negative

7d. Were there any factors affecting your experience as you answered?

8. Have you participated in any experiment in a traditional lab setting prior to this online experiment?

- Yes
- No

8a. If yes, how many experiments in traditional lab setting have you participated in prior to this online experiment?

- 1 to 3
- 4 to 6
- 7 to 9
- more than 9

8b. Please give some examples of experiments in a traditional lab setting you have participated in.

8c. Is your previous experience with participating in experiments in a traditional lab setting generally been positive or negative?

- Positive
- Negative

8d. Were there any factors affecting your experience as you answered?

9. Do you think an experiment conducted on the web can be representative of the real world work practices?

- Yes
- No

9a. Please explain why or why not?

10. Imagine a study involving a simulator and multiple participant-experimenter interactions. Would you be more likely to participate in this study delivered online or in a traditional lab setting?

- Online
- Traditional lab setting
- Does not matter

10a. Please explain why you choose your answer.

11. Please specify whether you like to enter the draw for a \$100 Amazon Gift Card.

- Yes
- No

12. Please provide a working email address for us to email you information about the specifics of the experiment and for scheduling purposes.

Appendix B

Post-Trial Questionnaire for All Participants

Instruction

In the questions below, you will be asked to rate several indicators based on your performance and understanding of the trial you have just completed. Please answer each question to the best of your ability. You may skip any questions you wish not to answer. Feel free to ask the experimenter any questions for clarification.

Please enter your participant ID

Trial #:

1) Confusion

You feel confused over what the controller was telling you to do. Agree or disagree?

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

2) Awareness of Own Situation

You had a good understanding of the traffic situation around the airport. Agree or disagree?

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral

- Somewhat Agree
- Agree
- Strongly Agree

3) Awareness of Pilot Participant's Situation

You had a good understanding of the controller participant's traffic situation throughout the trial. Agree or disagree?

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

4) Communication

The communication between you and the controller was effective. Agree or disagree?

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

5) Initial Resolution

I was satisfied with the controller's initial resolution maneuver to a potential collision with UAS. Agree or disagree?

- Strongly Disagree
- Disagree
- Somewhat Disagree

- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

6) Final Resolution

I was satisfied with the controller's final resolution maneuver to a potential collision with UAS.
Agree or disagree?

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

7) Notable Events / Observations

Any notable events or observation that you feel contributed to your overall experience in this trial?

Appendix C

Post-Experiment Survey on Information Asynchrony for Pilots

Instruction

This survey will help us have better insight into what professional experts say about "Information Asynchrony" in aviation. You may skip any questions you wish not to answer. Feel free to ask the experimenter for any clarification. "Information Asynchrony" can be described as the time difference between the time it takes for a pilot and a controller to receive data of a common source (Yuan et al., 2012). An example would be the pilot seeing the most up-to-date weather data on the navigation display while the controller is seeing the same information but 30 minutes old on the ATC radar display.

Please enter your participant ID

1. Have you ever experienced "Information Asynchrony" affecting communication with controller in your professional work?

- Yes
- No

1a. What are three keywords / phrases that describe how information asynchrony could or does affect communication in your professional work?

1b. What surveillance data were involved? Please select all that applies.

- Weather
- UAS
- Birdflocks
- Airliners

Others _____

1c. Please describe in detail how the flight operations were affected.

1d. Your experience of information asynchrony in the simulator trials is representative of the information asynchrony effects in your professional work. Agree or Disagree?

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

1e. Please list 3 aspects of the effect that are most representative and for each aspect briefly describe why.

1f. Please list 3 aspects of the effect that are most non-representative and for each aspect briefly describe why.

2. Please describe in detail what you would usually do to mitigate the effect of "Information Asynchrony" in your professional work.

2a. You employed the same methodology during the simulator trials. Agree or disagree?

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

2b. If any, please list some of the reasons to the difference in methodology during the simulator trials verses in your professional work?

3. Do you have any other comments or insights on "Information Asynchrony" that you would like to share?

Appendix D

Post-Experiment Survey on Information Asynchrony for Controllers

Instruction

This survey will help us have better insight into what professional experts say about "Information Asynchrony" in aviation. You may skip any questions you wish not to answer. Feel free to ask the experimenter for any clarification. "Information Asynchrony" can be described as the time difference between the time it takes for a pilot and a controller to receive data of a common source (Yuan et al., 2012). An example would be the pilot seeing the most up-to-date weather data on the navigation display while the controller is seeing the same information but 30 minutes old on the ATC radar display.

Please enter your participant ID

1. Have you ever experienced "Information Asynchrony" affecting communication with pilots in your professional work?

- Yes
- No

1a. What are three keywords / phrases that describe how information asynchrony could or does affect communication in your professional work?

1b. What surveillance data were involved? Please select all that applies.

- Weather
- UAS
- Birdflocks
- Airliners

Others _____

1c. Please describe in detail how the ATC operations were affected.

1d. Your experience of information asynchrony in the simulator trials is representative of the information asynchrony effects in your professional work. Agree or Disagree?

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

1e. Please list 3 aspects of the effect that are most representative and for each aspect briefly describe why.

1f. Please list 3 aspects of the effect that are most non-representative and for each aspect briefly describe why.

2. Please describe in detail what you would usually do to mitigate the effect of "Information Asynchrony" in your professional work.

2a. You employed the same methodology during the simulator trials. Agree or disagree?

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

2b. If any, please list some of the reasons to the difference in methodology during the simulator trials verses in your professional work?

3. Do you have any other comments or insights on "Information Asynchrony" that you would like to share?

Appendix E

Post-Experiment Survey on Participation Experience for All Participants

Instruction

This survey will help us better understand how well the online experiment methodology work out in delivering this study online verses in a traditional lab setting. There are two parts to this survey. The survey asks for your participation experience in this online study, as well as your opinion on delivering similar studies online verses traditional lab settings. You may skip any questions you wish not to answer. Feel free to ask the experimenter for any clarification.

Please enter your participant ID

1. Do you think an experiment conducted on the web can be representative of real world work practices?

- Yes
- No

1a. Please list some reasons as to why or why not.

2. What are 3 keywords or phrases that come to mind that describes the positive characteristics of this study being conducted online?

3. What are 3 keywords or phrases that come to mind that describe the negative characteristics of this study being conducted online?

4. You feel comfortable with participating in the recruitment process administered online as done in this study (from receiving recruitment email to simulator schedule being finalized). Agree or disagree?

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neither Agree Nor Disagree
- Somewhat Agree
- Agree
- Strongly Agree

4a. What are three key suggestions to the online recruitment process you can think of that can help future participants to feel more comfortable participating in similar studies?

5. You feel comfortable with the online communicating process with the experimenter and other participants as implemented in this study during the simulator session. Agree or disagree?

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neither Disagree Nor Agree
- Somewhat Agree
- Agree
- Strongly Agree

5a. What are three key suggestions to the online communication implementation you can think of that can help future participants to feel more comfortable participating in similar studies?

6. You feel comfortable with the video-only simulator as done in this study during the simulator session. Agree or disagree?

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neither Disagree Nor Agree
- Somewhat Agree
- Agree
- Strongly Agree

6a. What are three key suggestions to the simulator implementation you can think of that can help future participants to feel more comfortable participating in similar studies?

7. What are 3 keywords or phrases that comes to mind that describe the most important characteristic elements required to successfully deliver similar studies online, compared to a physical lab setting?

8. Would you participate in this or other studies again in the future?

- Yes
- No

8a. Please explain why or why not.

9. After participating in this study online, would you more likely to participate in this or similar studies delivered online or in a traditional lab setting?

- Online
- Traditional lab setting
- Does not matter

10. Do you have any final comments?

Appendix F

Briefing Documents for Simulator Session for Pilots

This document contains very important information for the upcoming simulator session. Please go through carefully.

Big Picture

You will be:

1. Paired with a TRACON controller participant.
2. Participating in simulated flight operations as a pilot on a simulator over the web.
3. Communicating with the controller participant and experimenter online.
4. Answering questionnaires and surveys.

Equipment Check

For your simulator session, please make sure:

1. Use PC only
2. Have speaker and microphone (best to use a headset)
3. Use Google Chrome for internet browser (download link below)
 - <https://www.google.com/chrome/browser/#eula>

Session Procedure

You will be asked to:

1. Receive login information in email 1 hour before session.
2. Log onto simulator session.
3. Establish communication online with the experimenter and controller participant through online conference "Google Hangout" service.
4. Go through 2 training scenarios for simulator procedure familiarization.
5. Go through 9 formal trials.
6. Answer a trial questionnaire after each trial.
7. Answer two surveys.
8. Read feedback letter and logoff - end of experiment.

Specifics on your Pilot Role

1. Assuming the role of a pilot-monitoring (PM).
2. Communicate with the experimenter as your pilot-flying (PF).
3. Communicate with the controller participant.

Simulator Operation

You will be presented a real-time navigation display with surveillance data including: airliners, UAS and birdflocks. You will be engaged in landing and takeoff operations from a fictional "Campus Regional Airport" (YWCX) in Canada. Please assume:

1. Your aircraft is in the class of a B737-700 sized aircraft.
2. Night time operation.
3. 3 nm lateral separation.
4. RNAV SID / STAR procedure with radar vector to SID / intercept localizer.

Arrival Procedure:

Your flight activity will centre around being radar vectored to intercept localizer to runway 13 until crossing the Final Approach Point:

1. Maintain given speed, altitude and heading after last waypoint of the arrival route.
2. Receive radar vector from Campus Arrival 123.56 to intercept localizer.
3. Contact tower 118.25 after crossing Final Approach Point (10 miles from airport) at 2000ft

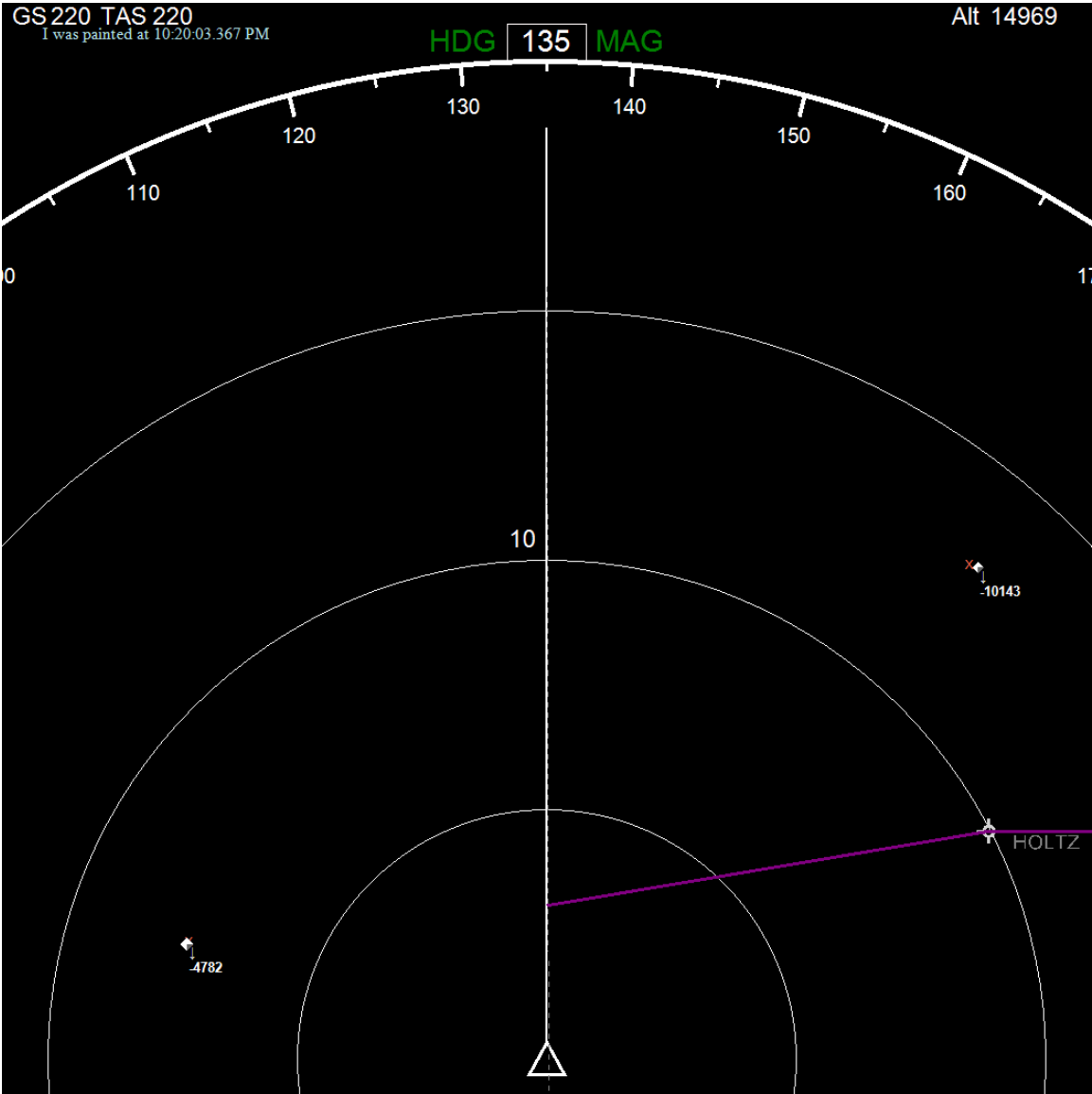
Departure Procedure:

Your flight activity will centre around being radar vectored to assigned RNAV SID after takeoff from Runway 13:

1. Contact Campus Departure 122.56 after passing around 3000 ft.
2. Expect climb to 12000 after contact.
3. Maintain speed 220, heading 135 until clearance to assigned departure route.

Please familiarize yourself with the navigation display and flight charts below.

Simulator Navigation Displays



STAR (RNAV) RWY 13

Canada Air Pilot

1

STAR (RNAV) RWY 13
BAYER ONE ARR (BAYER1)

Campus Regional
 WATERLOO, ON

CAMPUS ARRIVAL	123.56	WHEN A LOWER ALTITUDE IS ISSUED, PILOTS SHALL DESCEND ON THE STAR PROFILE TO THE ATC ASSIGNED ALTITUDE. CHARTED RESTRICTIONS ABOVE THE ASSIGNED ALTITUDE REMAIN MANDATORY.
TWR	118.25	

Jet Aircraft only

••• → EXPECT RADAR VECTORS TO FINAL APPROACH

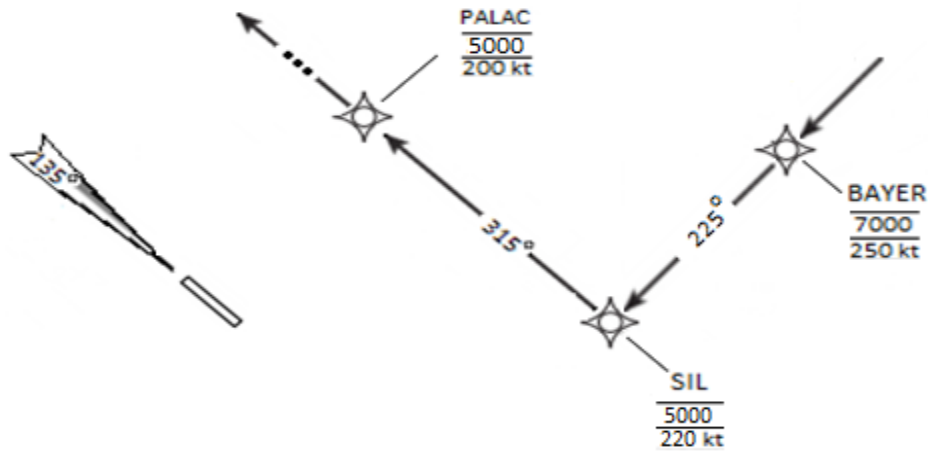


Chart not to scale

BAYER ONE ARR (BAYER1)

WATERLOO, ON
 Campus Regional

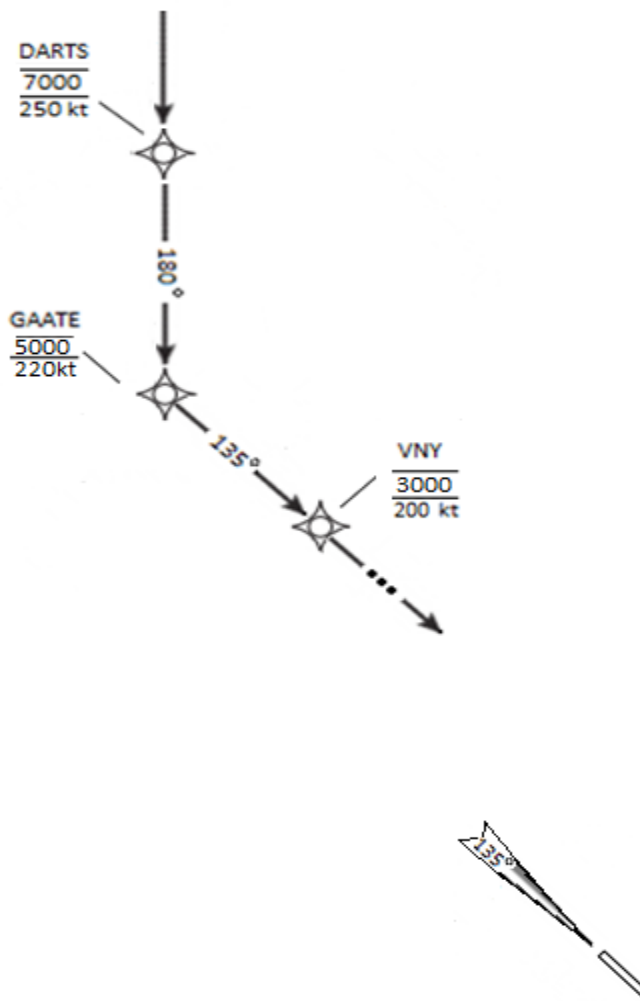
STAR (RNAV) RWY 13
DARTS ONE ARR (DARTS1)

Campus Regional
 WATERLOO, ON

CAMPUS ARRIVAL TWR	123.56 118.25	WHEN A LOWER ALTITUDE IS ISSUED, PILOTS SHALL DESCEND ON THE STAR PROFILE TO THE ATC ASSIGNED ALTITUDE. CHARTED RESTRICTIONS ABOVE THE ASSIGNED ALTITUDE REMAIN MANDATORY.
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Jet Aircraft only

••• → EXPECT RADAR VECTORS TO FINAL APPROACH



Not for Navigation

Chart not to scale

DARTS ONE ARR (DARTS1)

WATERLOO, ON
 Campus Regional

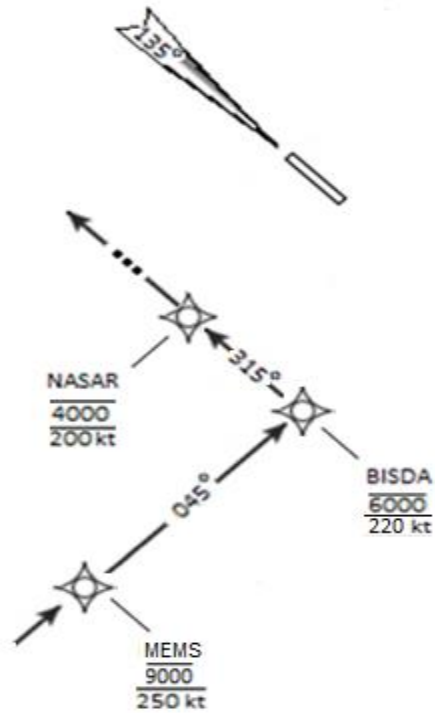
STAR (RNAV) RWY 13
MEMS ONE ARR (MEMS1)

Campus Regional
 WATERLOO, ON

CAMPUS ARRIVAL	123.56	WHEN A LOWER ALTITUDE IS ISSUED, PILOTS SHALL DESCEND ON THE STAR PROFILE TO THE ATC ASSIGNED ALTITUDE. CHARTED RESTRICTIONS ABOVE THE ASSIGNED ALTITUDE REMAIN MANDATORY.
TWR	118.25	

Jet Aircraft only

••• → EXPECT RADAR VECTORS TO FINAL APPROACH



Not for Navigation

Chart not to scale

MEMS ONE ARR (MEMS1)

WATERLOO, ON
 Campus Regional

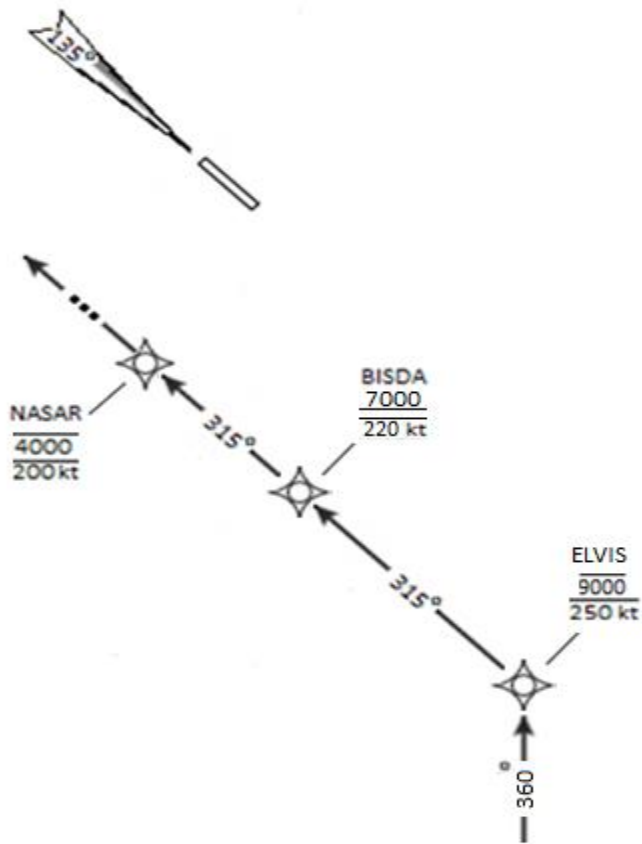
STAR (RNAV) RWY 13
ELVIS ONE ARR (ELVIS1)

Campus Regional
 WATERLOO, ON

CAMPUS ARRIVAL TWR	123.56 118.25	WHEN A LOWER ALTITUDE IS ISSUED, PILOTS SHALL DESCEND ON THE STAR PROFILE TO THE ATC ASSIGNED ALTITUDE. CHARTED RESTRICTIONS ABOVE THE ASSIGNED ALTITUDE REMAIN MANDATORY.
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Jet Aircraft only

••• → EXPECT RADAR VECTORS TO FINAL APPROACH



Not for Navigation

Chart not to scale

ELVIS ONE ARR (ELVIS1)

WATERLOO, ON
 Campus Regional

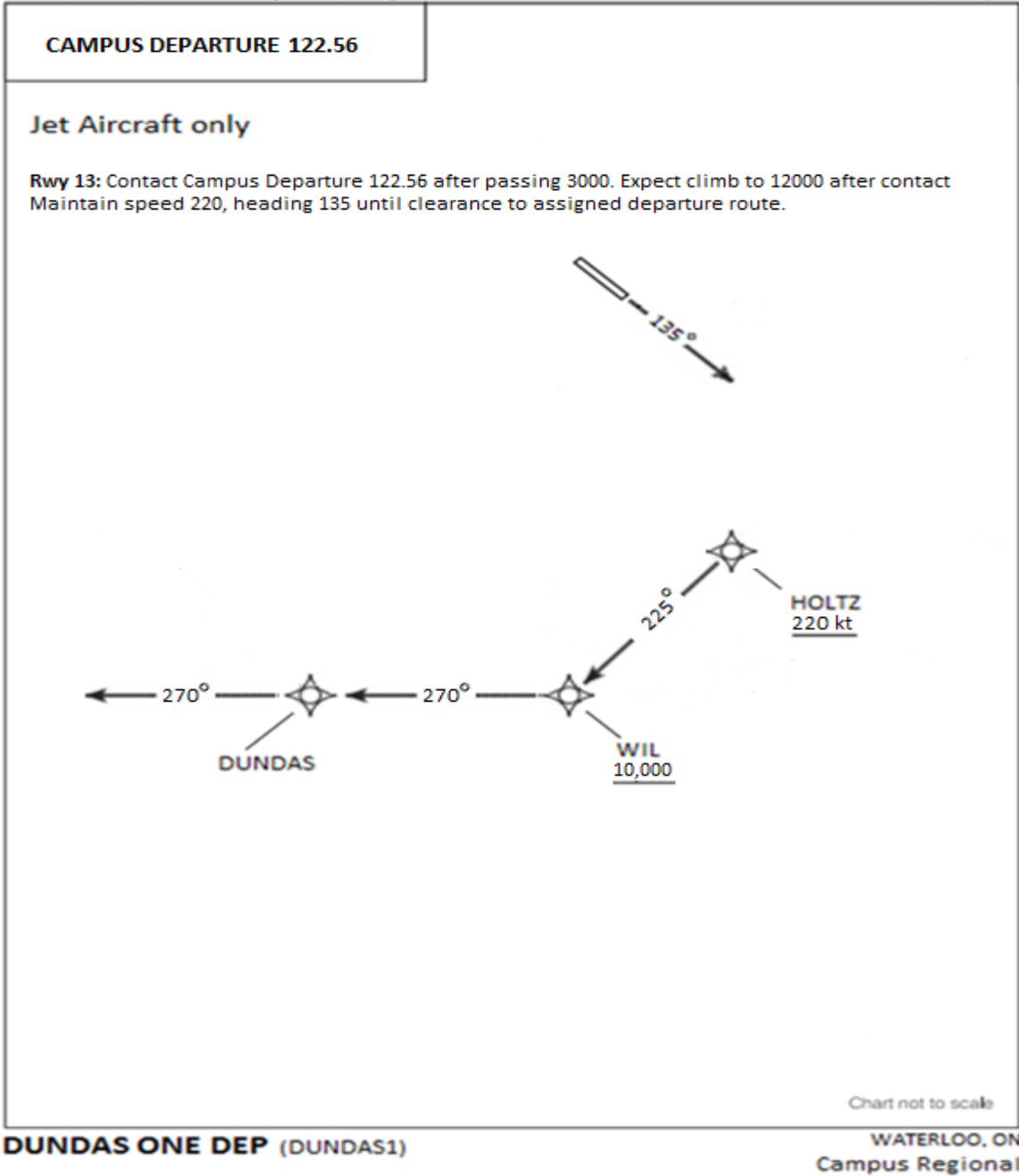
SID (RNAV) RWY 13

Canada Air Pilot

5

SID (RNAV) RWY 13
DUNDAS ONE DEP (DUNDAS1)

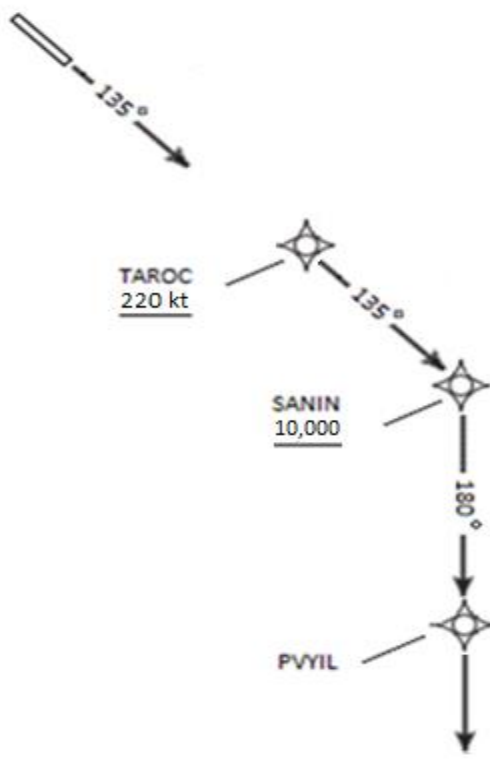
Campus Regional
WATERLOO, ON



CAMPUS DEPARTURE 122.56

Jet Aircraft only

Rwy 13: Contact Campus Departure 122.56 after passing 3000. Expect climb to 12000 after contact. Maintain speed 220, heading 135 until clearance to assigned departure route.



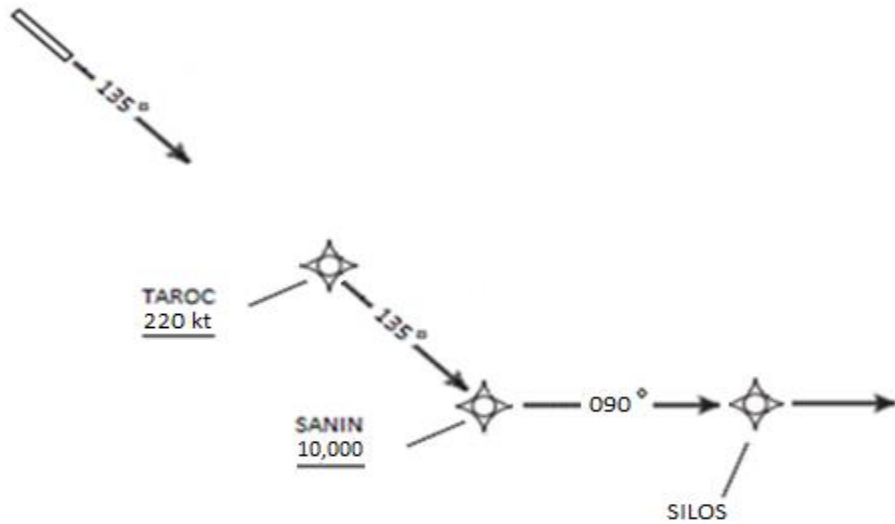
Not for Navigation

Chart not to scale

CAMPUS DEPARTURE 122.56

Jet Aircraft only

Rwy 13: Contact Campus Departure 122.56 after passing 3000. Expect climb to 12000 after contact. Maintain speed 220, heading 135 until clearance to assigned departure route.



Not for Navigation

Chart not to scale

Appendix G

Briefing Documents for Simulator Session for Controllers

This document contains very important information for the upcoming simulator session. Please review carefully.

The Big Picture

You will be:

1. Paired with a professional pilot participant.
2. Participating in simulated ATC operations as a TRACON controller on a simulator over the web.
3. Communicating with the pilot participant and experimenter online.
4. Answering questionnaires and surveys.

Equipment Check

For your simulator session, please make sure:

1. Use PC only
2. Have speaker and microphone (best to use a headset)
3. Use Google Chrome for internet browser (download link below)
 - o <https://www.google.com/chrome/browser/#eula>

Session Procedure

You will be asked to go through the following session activities:

1. Receive login information in email 1 hour before session
2. Log onto simulator session
3. Establish communication online with experimenter and controller participant using online conference "Google Hangout" service.
4. Go through 2 training and 9 formal trials
5. Answer a trial questionnaire after each trial
6. Answer two surveys
7. Read letter of appreciation and logoff

Your Role as Controller

1. Assume the role of a TRACON arrival and departure controller.
2. Manage your airspace.
 - Communicate with pilot participant for his or her aircraft.
 - Communicate with the experimenter for all other airliners.

Simulator Operation

You will be provided a real-time ATC radar display with surveillance data including: airliners, UAS and birdflock. You will be responsible for either TRACON arrival or departure from a fictional "Campus Regional Airport" (YWCX) in Canada. Please assume:

1. All aircrafts are B737-700 sized aircraft (except UAS) unless otherwise briefed.
2. Night time operation.
3. 3 nm lateral separation.
4. Assume your airspace 0 - 14,000 ft. AGL for both arrival and departure.
5. Assume surrounding airspace 4000 - 22000 ft. AGL.
6. RNAV SID / STAR procedure with radar vector to clear SID / intercept localizer.
7. UAS and bird flock are non-responsive.

Arrival Procedure

The TRACON arrival procedure involves the following as Campus Arrival 123.56 for Runway 13:

1. Radar vector aircrafts to intercept localizer. Aircrafts will maintain last RNAV STAR waypoint speed, altitude and heading until you provide them the radar vector.
2. Have aircraft intercept localizer at the appropriate green altitude marker according to aircraft altitude.
3. Hand off aircraft to tower 118.25 after crossing Final Approach Point at 2000 ft. 10 miles from airport.

Departure Procedure

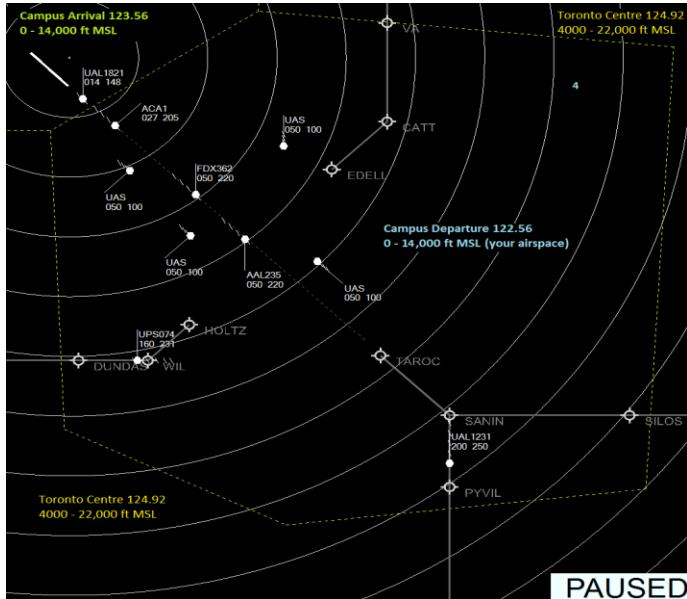
As Campus Departure 122.56 for Runway 13, climb-out departure procedure involves:

1. Acknowledge aircraft contacting you after passing around 3000 ft.
2. Climb aircraft to 12,000. Try to clear aircraft direct to appropriate route approximately 20 nautical miles out.

- Please hold aircraft until 10 nautical miles before boundary, then pass aircraft to Toronto Centre 124.92.

Please familiarize yourself with the simulator ATC display and flight charts below.

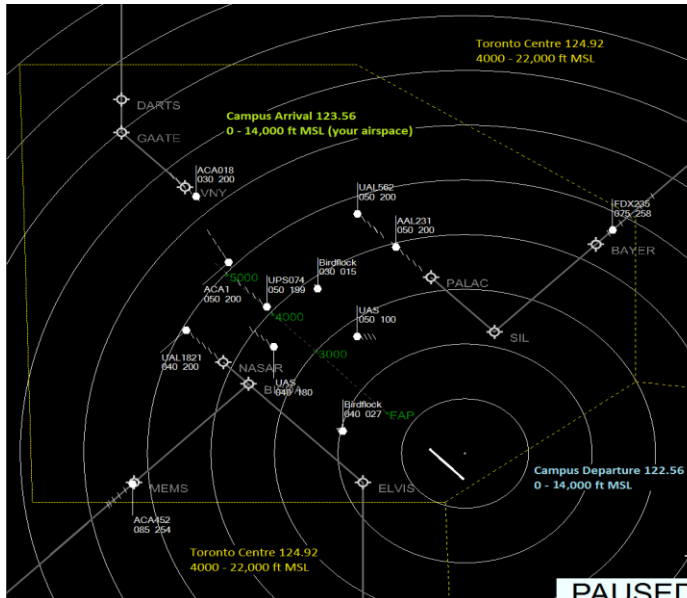
ATC Radar Map RWY 13 Takeoff



You have the board. Departure Runway 13. Wind calm. No significant weather. UAL1821 has taken off from runway 13 at 1384 ft. ACA1 at 2727 ft. FDX362 and AAL235 needs a turn to PYVIL1 and VA1 respectively. Pass UAL1231 and UPS074 to Toronto Centre 124.92. UPS018 and AAL2156 will take off at 00:01:20 and 00:02:40 respectively after scenario starts. You have UAS - 17.3 nm from the airport at 5002 ft, speed 100, and 24.7 nm from the airport at 5000 ft, speed 100. You have UAS - 10.4 nm from the airport at 5000 ft, speed 100 and 17.1 nm from the airport at 5000 ft, speed 100.

UAL1231 B737 1	CZYZ /Q	1111 00:00:00 410	YWCX	PYVIL1			
AAL2156 B737 2	CZYZ /Q	2222 00:02:40 410	YWCX	VA1			
FDX362 B737 3	CZYZ /Q	3333 00:00:00 410	YWCX	PYVIL1			
UAL1821 B737 4	CZYZ /Q	4444 00:00:00 410	YWCX	VA1			
UPS074 B737 5	CZYZ /Q	5555 00:00:00 410	YWCX	DUNDAS1			
ACA1 B737 6	CZYZ /Q	7777 00:00:00 410	YWCX	PYVIL1			
AAL235 B737 7	CZYZ /Q	8888 00:00:00 410	YWCX	VA1			
UPS018 B737 8	CZYZ /Q	1010 00:01:20 410	YWCX	PYVIL1			

ATC Radar Map RWY 13 Landing



You have the board. ILS Runway 13. Wind 315 degree 10 knot. ACA018 - UAL1821, UAL562 and AAL231 need a turn to intercept localizer. FDX235 and ACA452 have been clearance for their respective arrivals. ACA1 is 1 nm from intercepting localizer on heading 150. You have a UAS at 4976 ft, speed 100, 13.6 nm to your aircraft bearing 321 degrees, and one at 4000 ft, speed 180, 17.9 nm to your aircraft bearing 303 degrees. You have Birdblock at 3884 ft, speed 27, 9.8 nm to your aircraft bearing 282 degrees, and at 3000 ft, speed 15, 19 nm to your aircraft bearing 322 degrees.

AAL231 B737 1	CZYZ /Q	1111 BAYER1 FAP	N/A	5000	YWCX		ILS FS
ACA452 B737 2	CZYZ /Q	2222 MEMS1 FAP	N/A	8500	YWCX		ILS FS
UAL562 B737 3	CZYZ /Q	3333 BAYER1 FAP	N/A	5000	YWCX		ILS FS
UAL1821 B737 4	CZYZ /Q	4444 ELVIS1 FAP	N/A	4000	YWCX		ILS FS
UPS074 B737 5	CZYZ /Q	5555 BAYER1 FAP	N/A	5000	YWCX		ILS FS
ACA1 B737 6	CZYZ /Q	7777 ELVIS1 FAP	N/A	5000	YWCX		ILS FS
FDX235 B737 7	CZYZ /Q	8888 BAYER1 FAP	N/A	7100	YWCX		ILS FS
ACA018 B737 8	CZYZ /Q	1010 DARTS1 FAP	N/A	3000	YWCX		ILS FS

Note: Same flight charts as those in briefing document for pilots.

Appendix H

Raw Subjective Rating Data from Post-Trial Questionnaire

This appendix presents the raw subjective ratings by participants from post-trial questionnaire. These are presented in the graphs below. Each graph presents the rating responses for each of the six questions in the post-trial questionnaire.

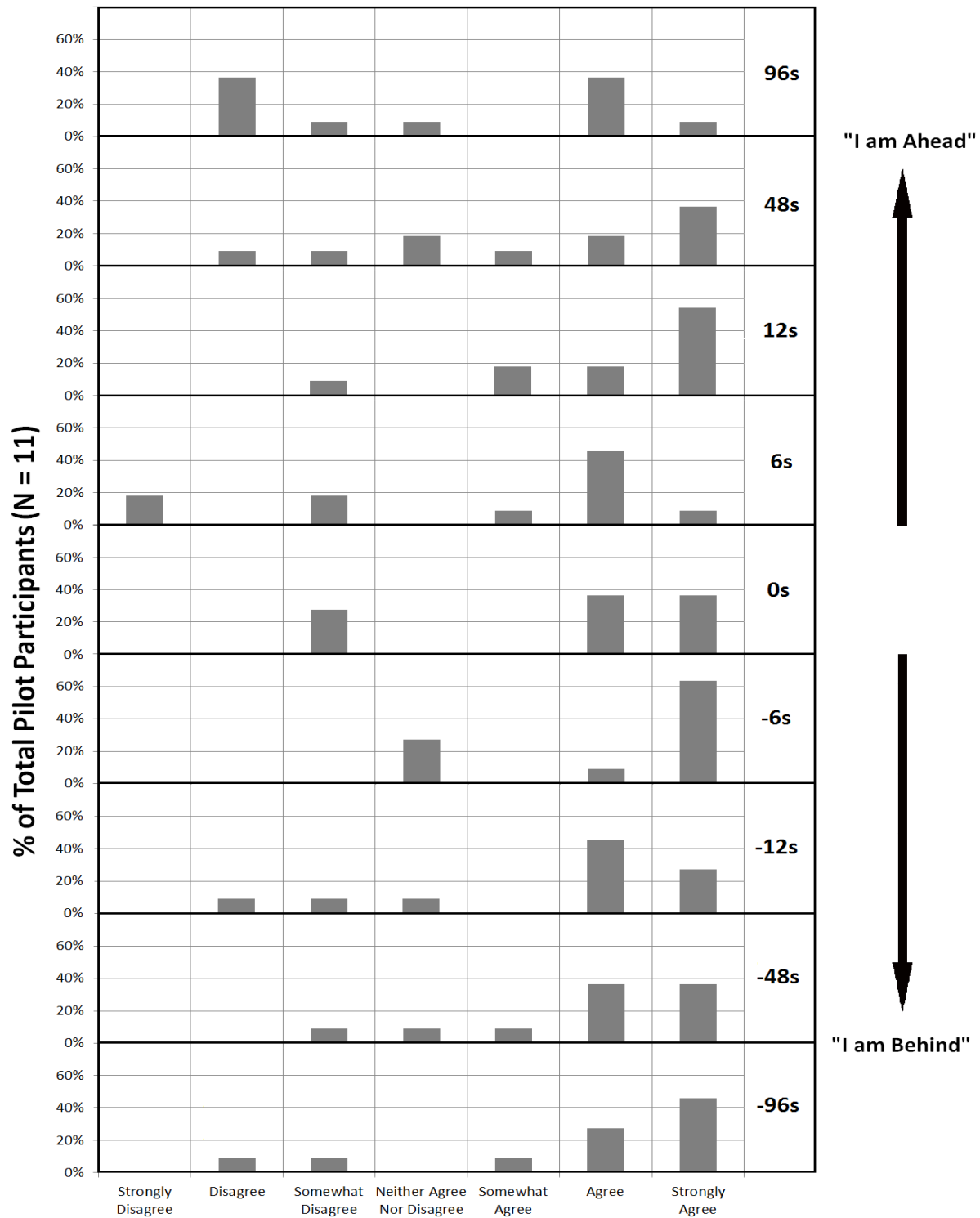


Figure H-1: Pilot participants' raw rating responses to the statement that they felt confused about the traffic situation (note "Agree" means more confused)

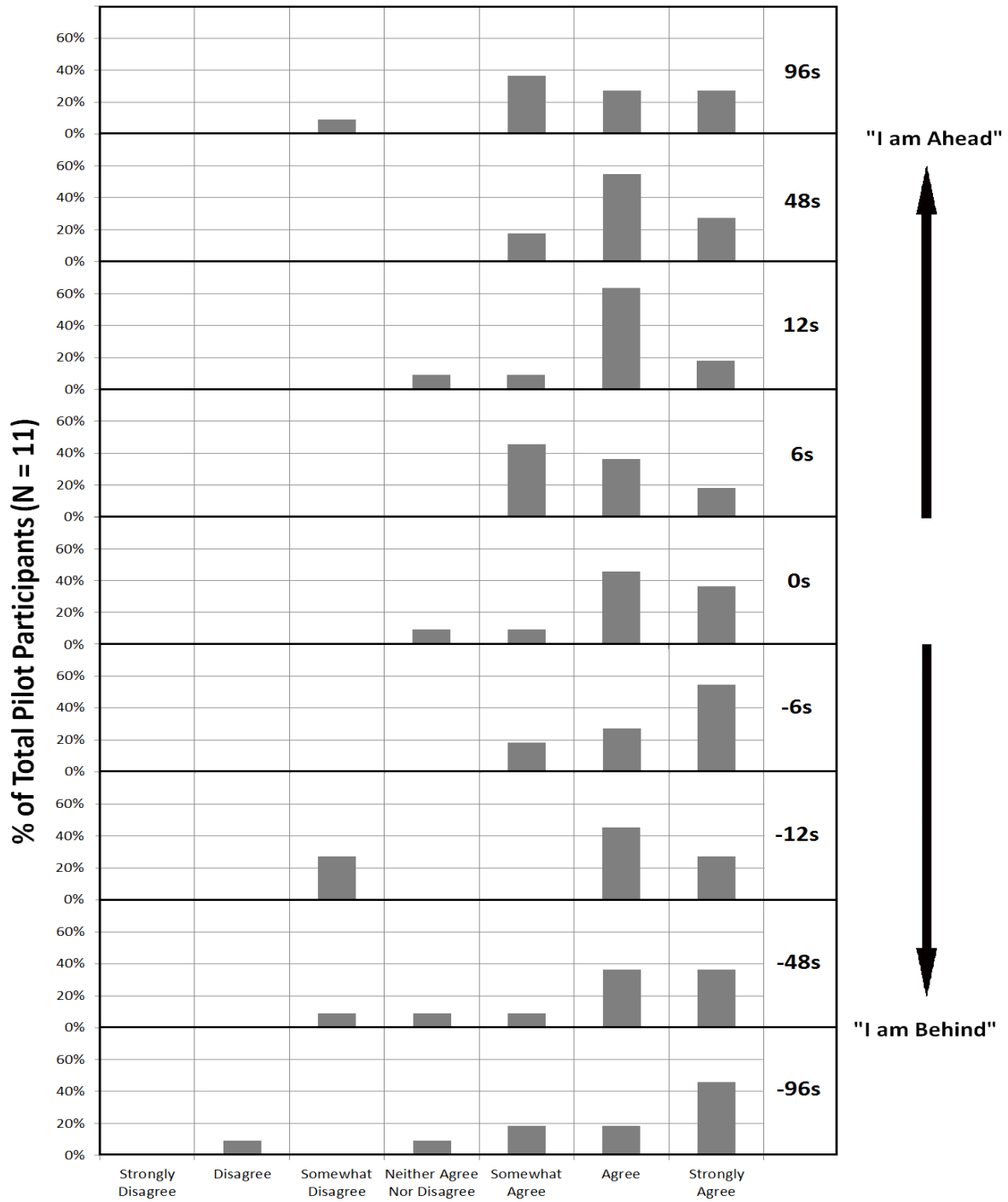


Figure H-2: Pilot participants' raw rating responses to the statement that they are aware of own traffic situation

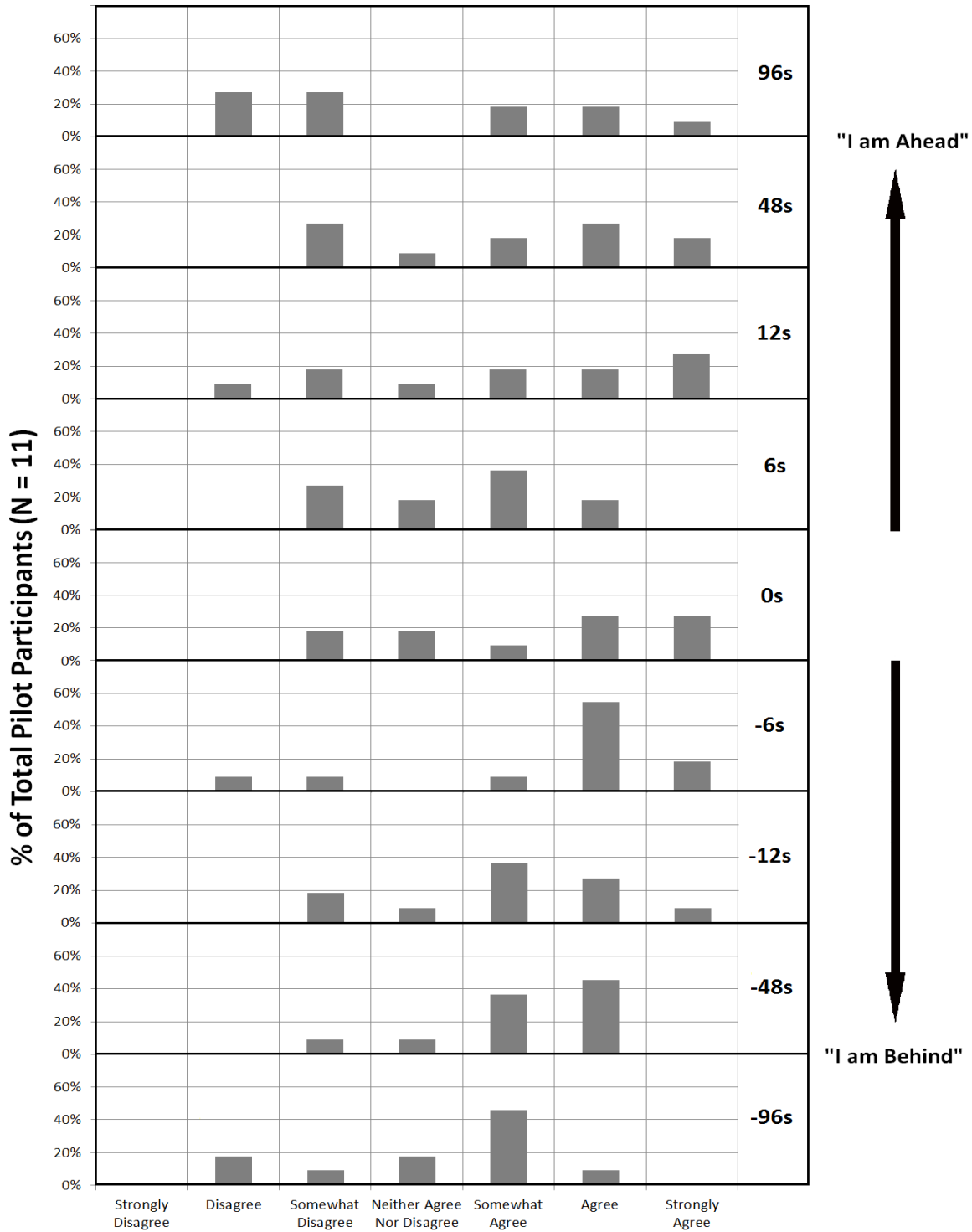


Figure H-3: Pilot participants' raw rating responses to the statement that they are aware of other party's traffic situation

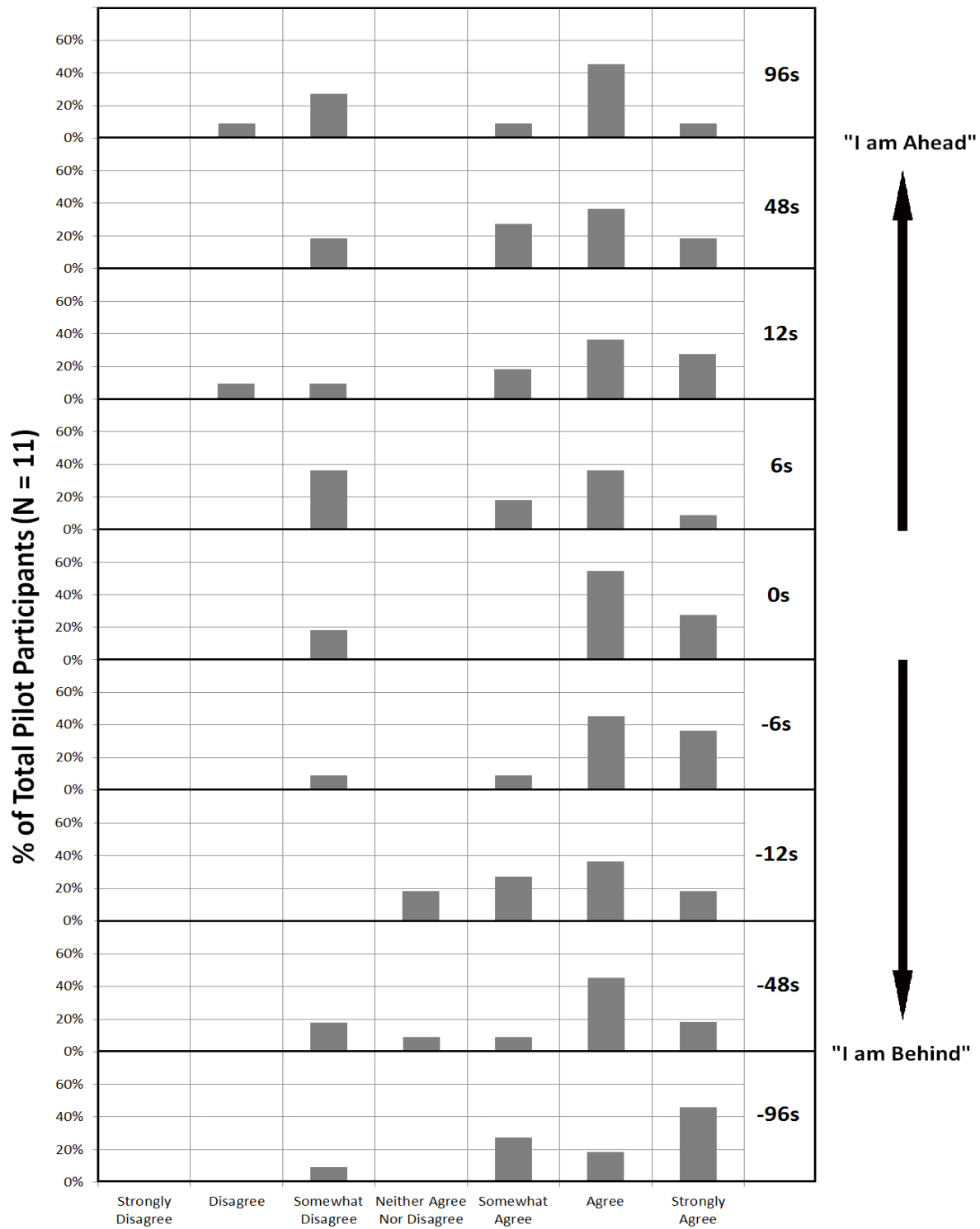


Figure H-4: Pilot participants' raw rating responses to the statement that the pilot-controller communication was effective

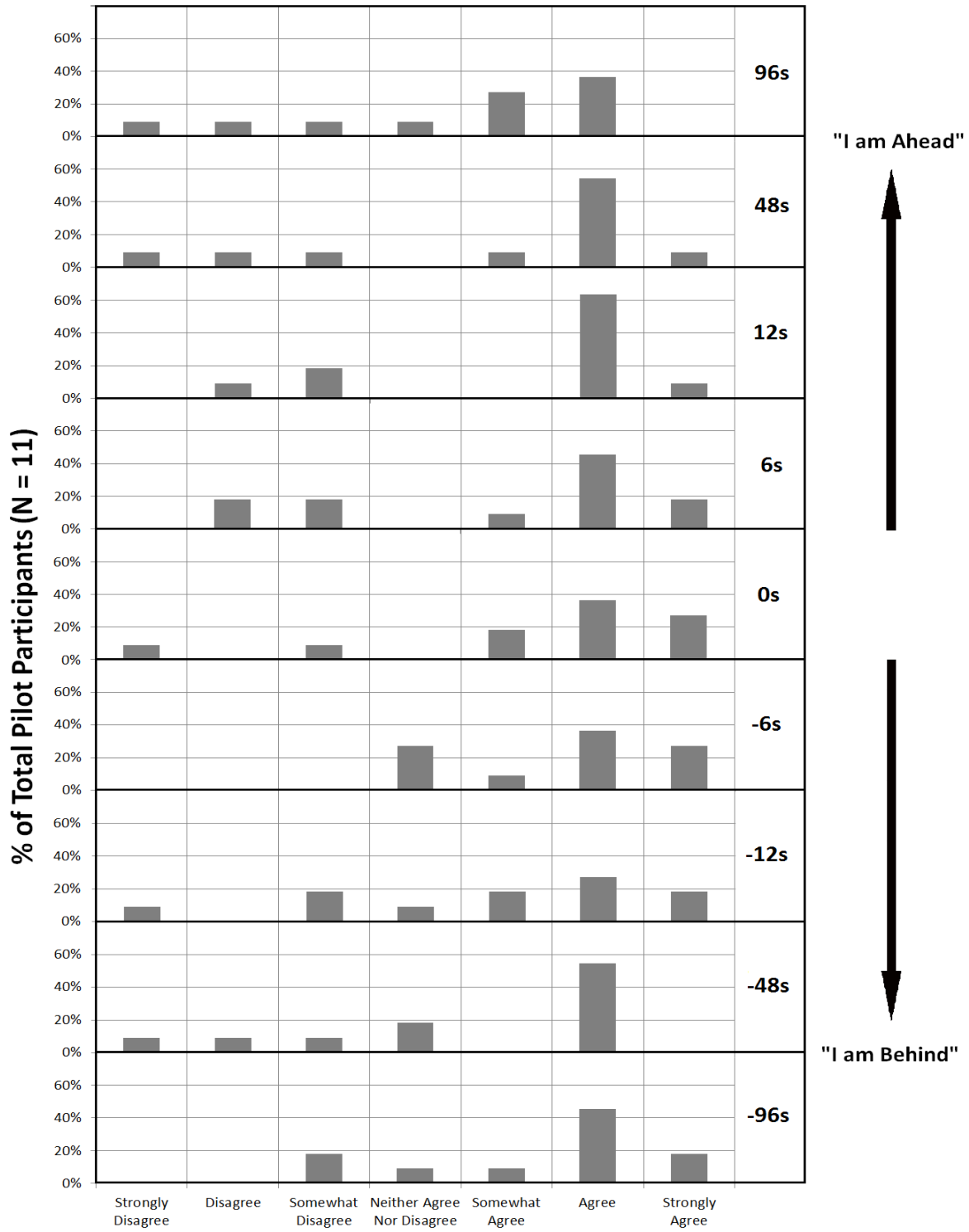


Figure H-5: Pilot participants' raw rating responses to the statement that they felt satisfied with other party's proposed / response to initial resolution

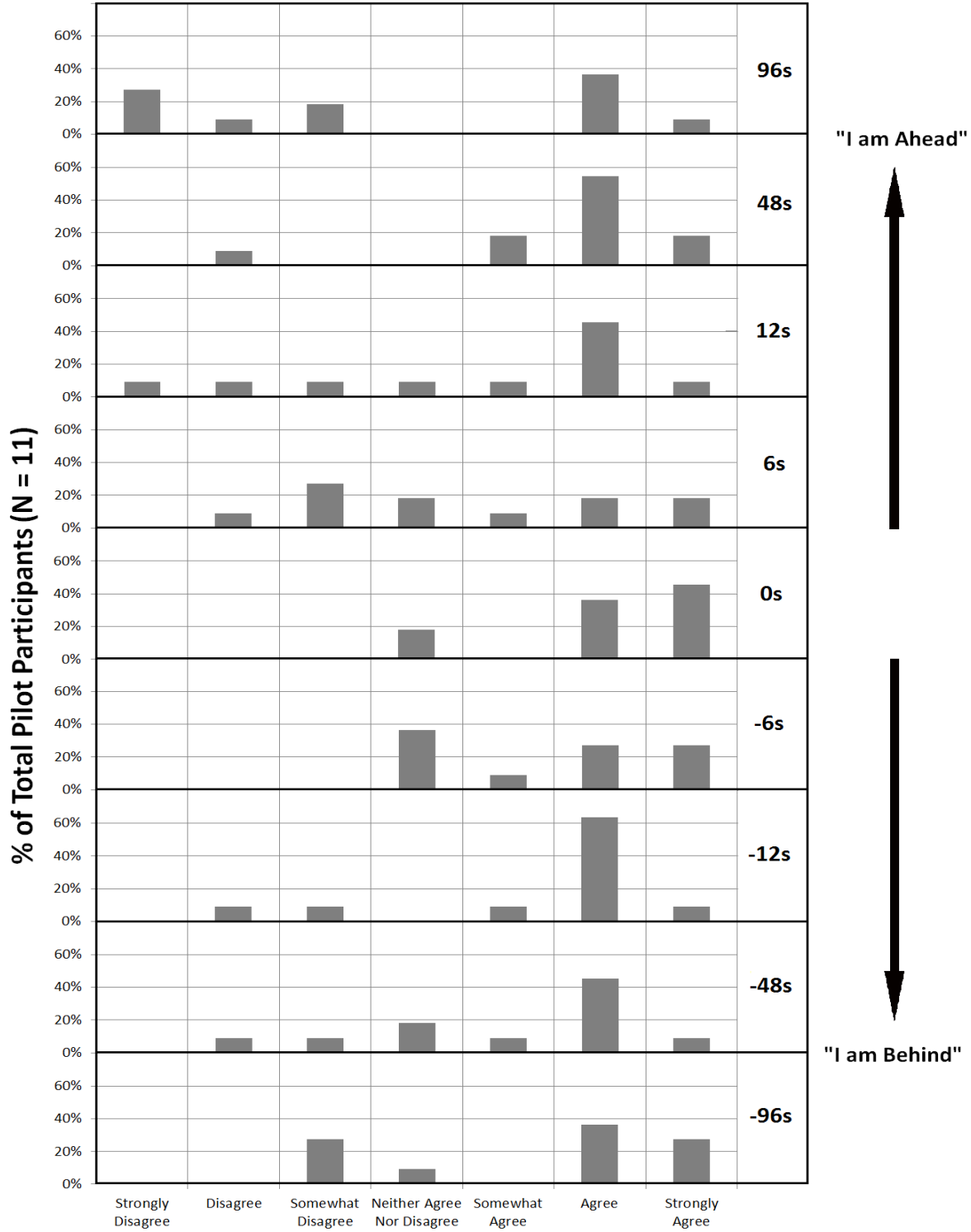


Figure H-6: Pilot participants' raw rating responses to the statement that they felt satisfied to other party's proposed / response to final resolution

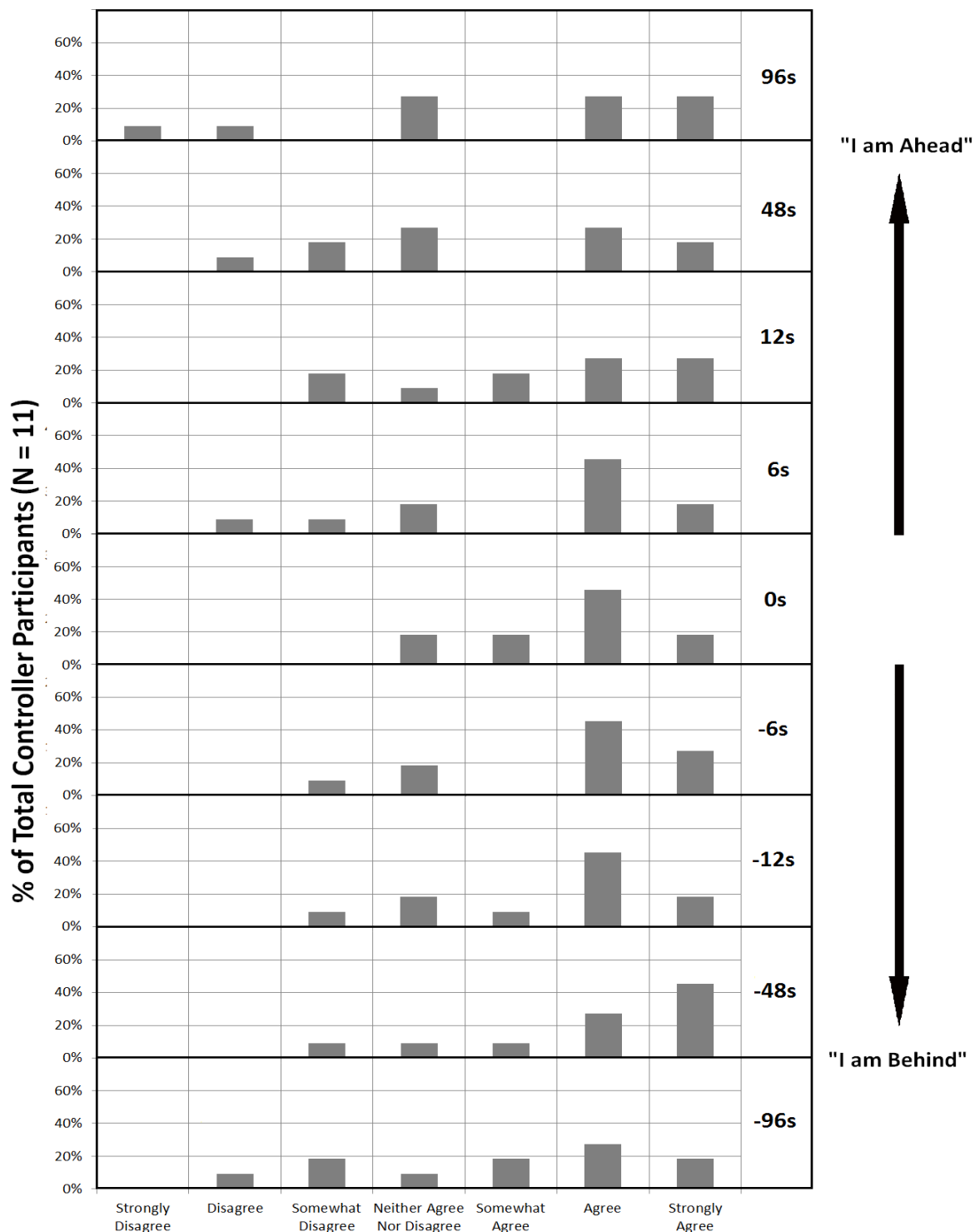


Figure H-7: Controller participants' raw rating responses to the statement that they felt confused about the traffic situation (note "Agree" means more confused)

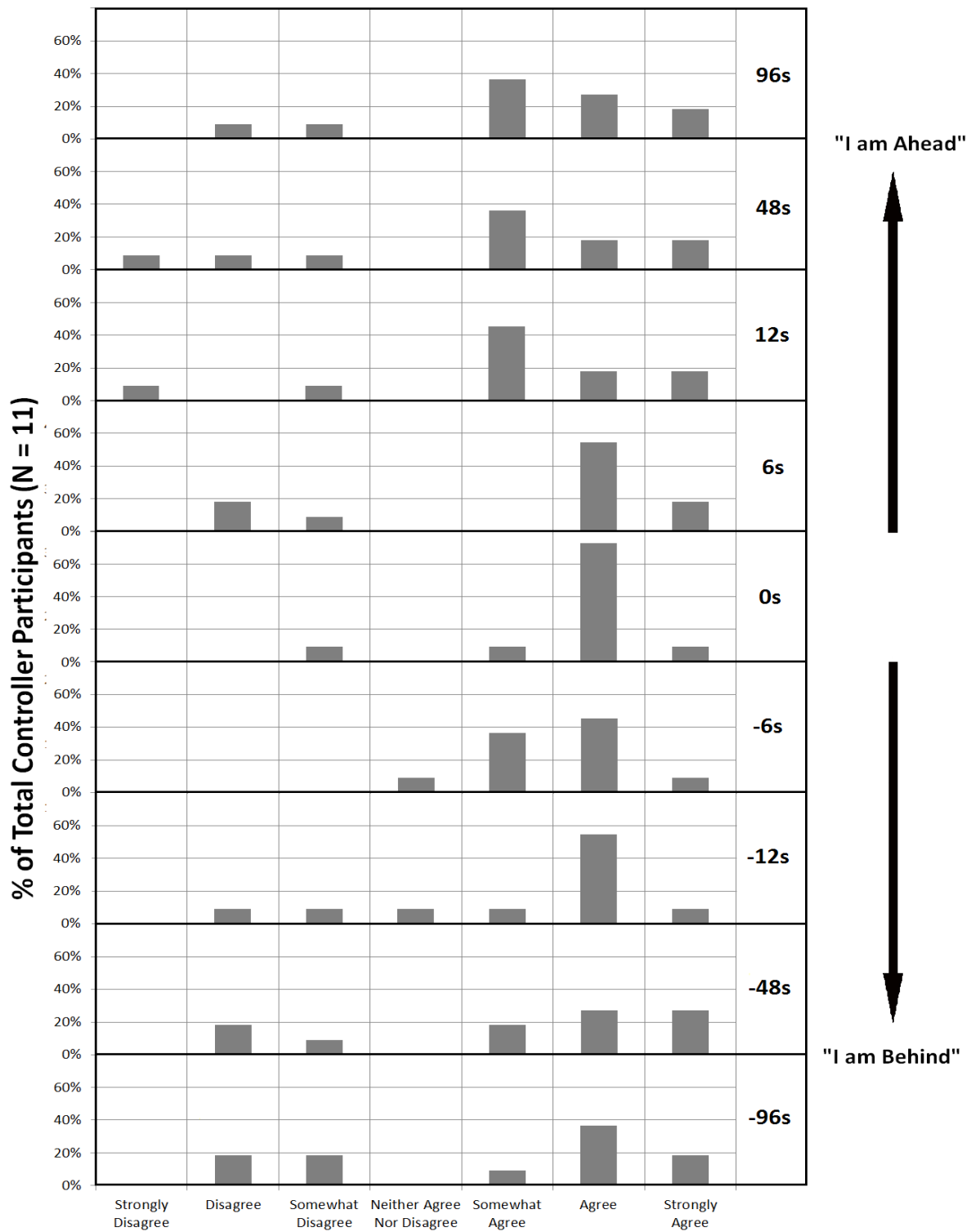


Figure H-8: Controller participants' raw rating responses to the statement that they are aware of own traffic situation

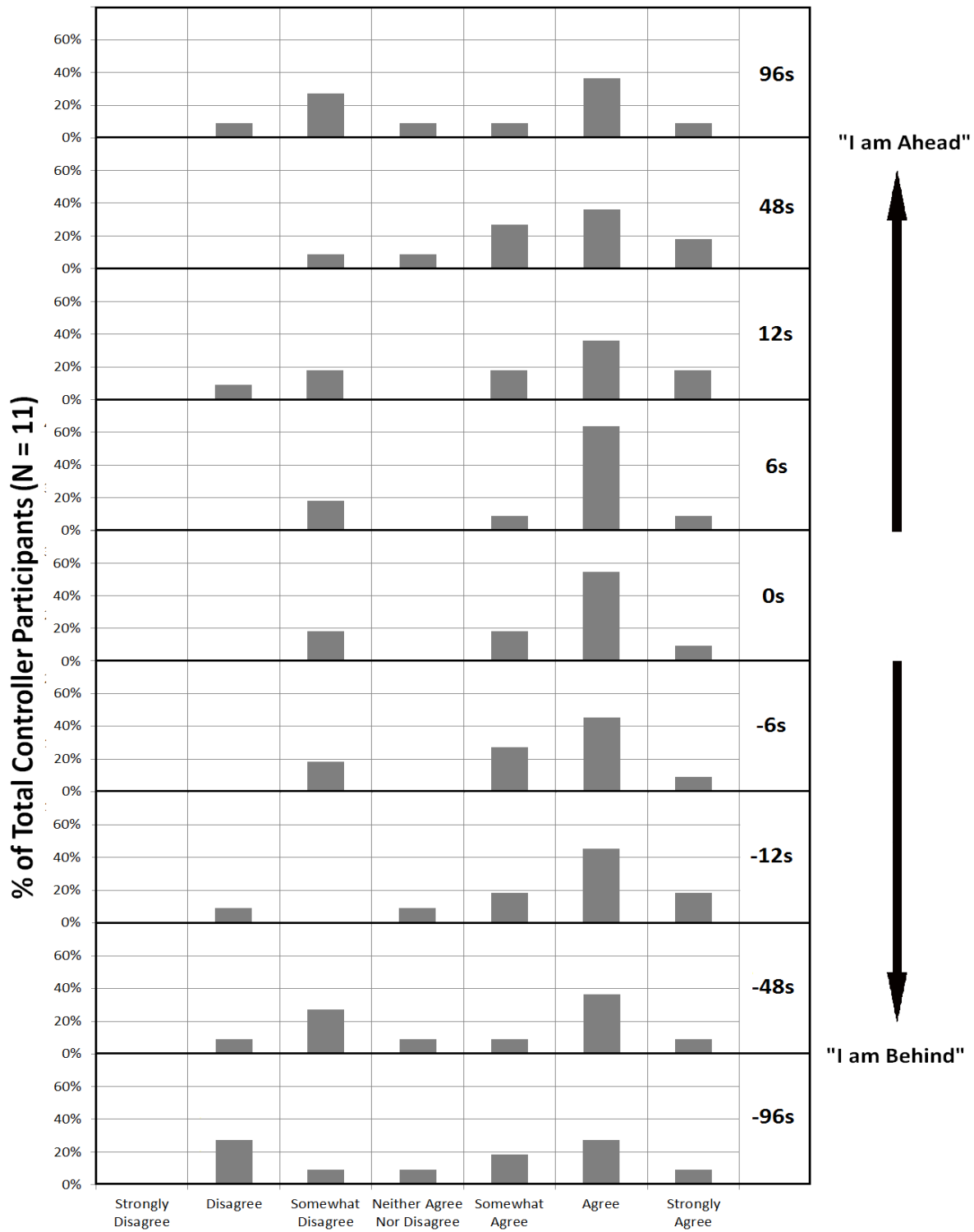


Figure H-9: Controller participants' raw rating responses to the statement that they are aware of other party's traffic situation

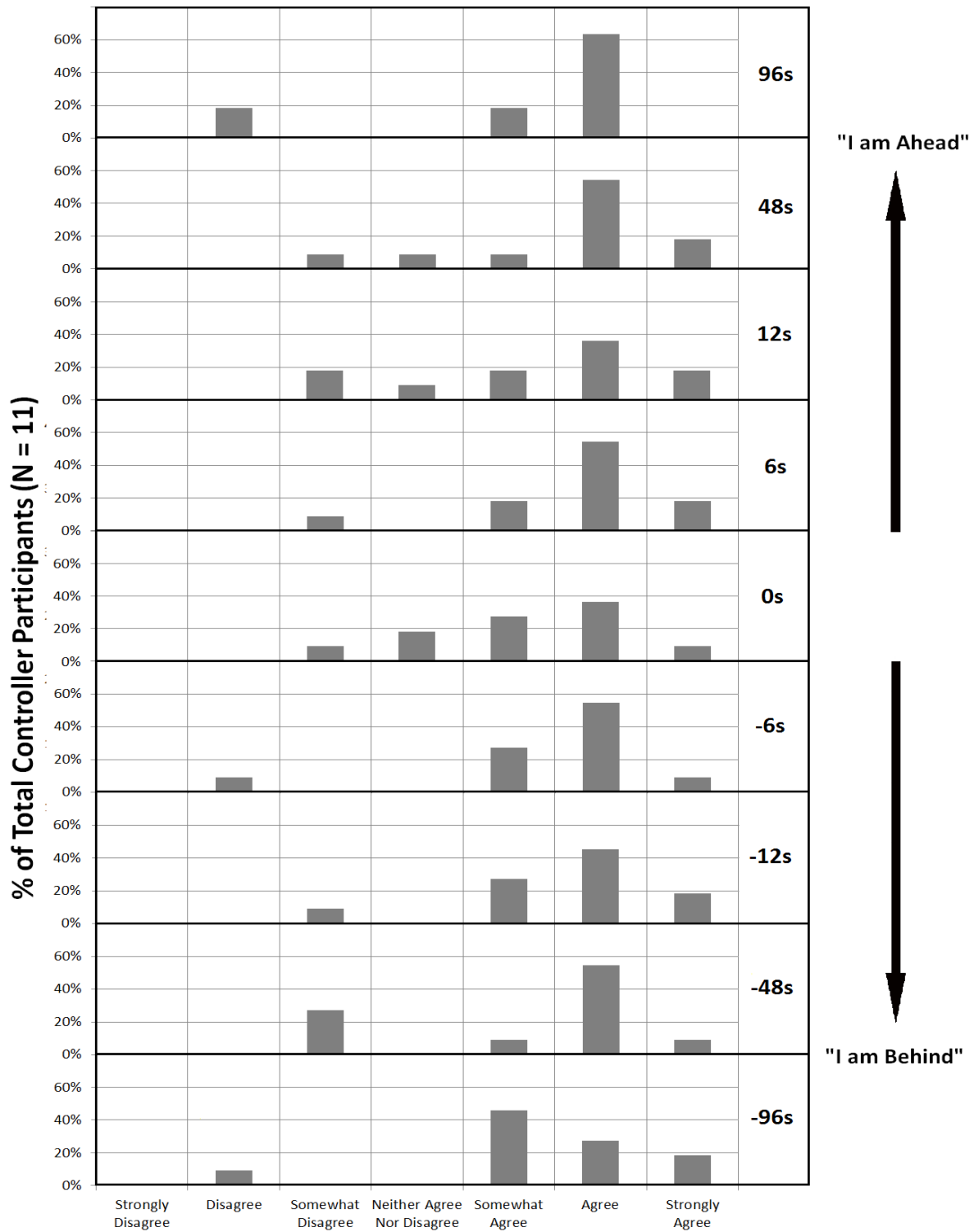


Figure H-10: Controller participants' raw rating responses to the statement that the pilot-controller communication was effective

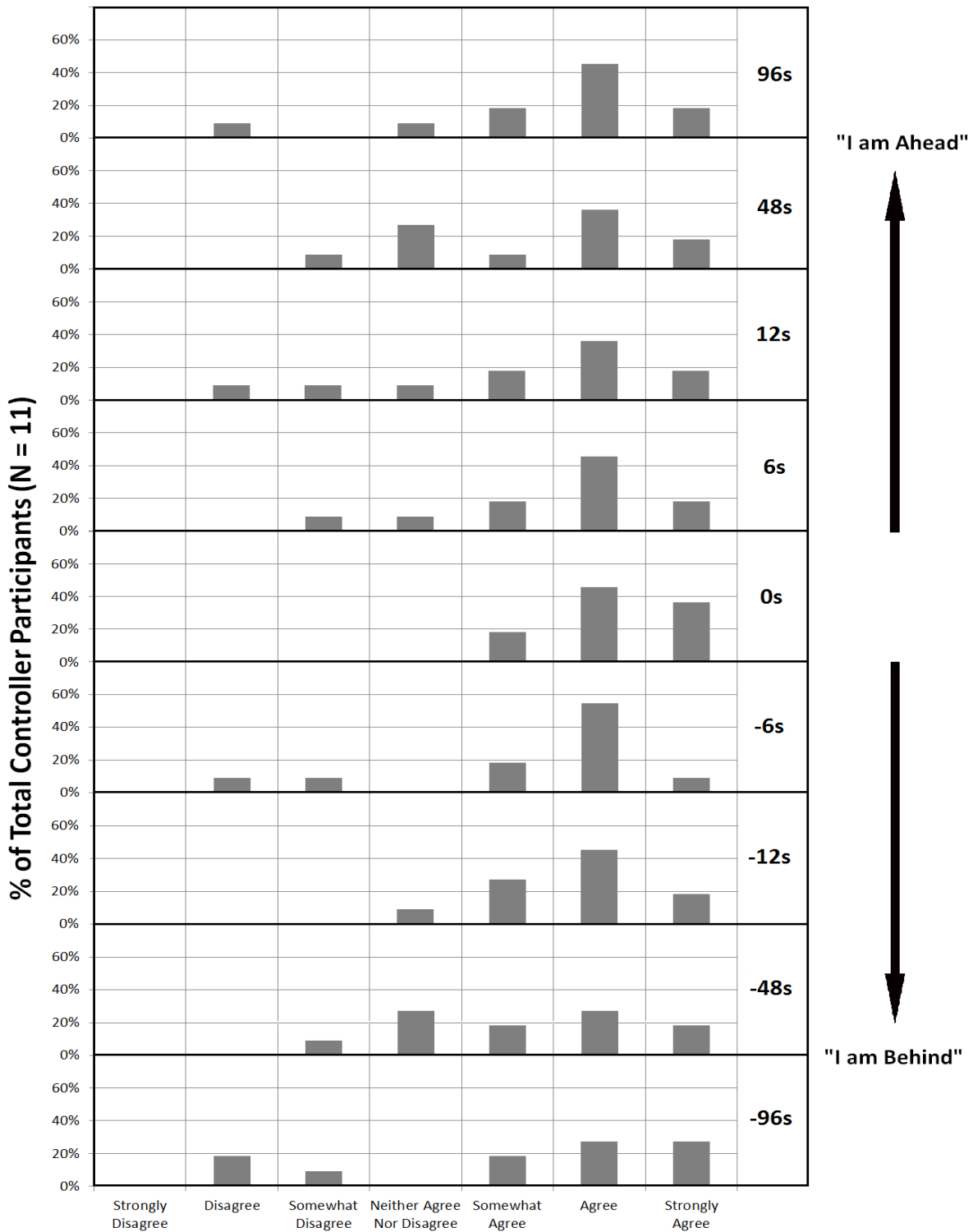


Figure H-11: Controller participants' raw rating responses to the statement that they felt satisfied with other party's proposed / response to initial resolution

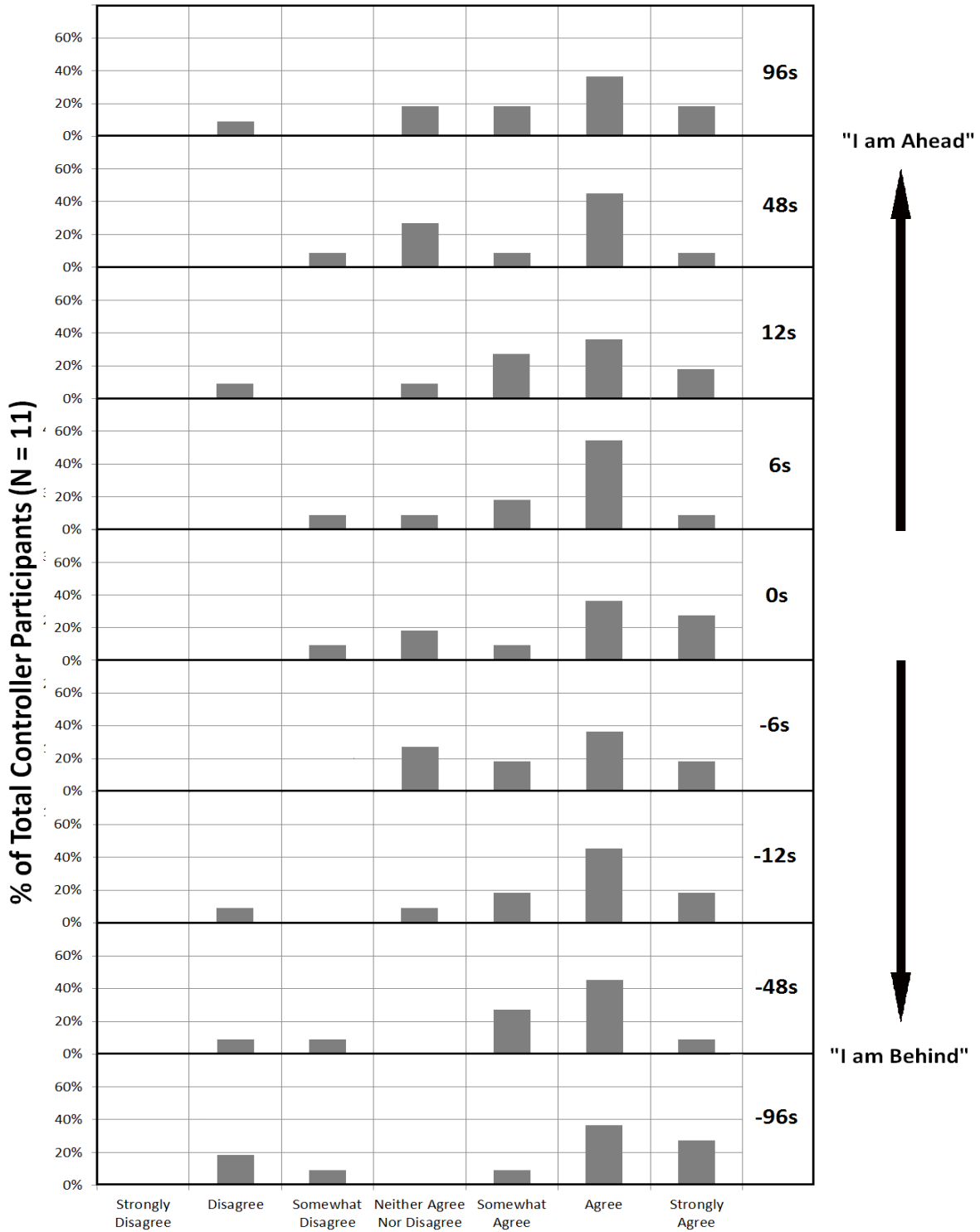


Figure H-12: Controller participants' raw rating responses to the statement that they felt satisfied to other party's proposed / response to final resolution

Appendix I

7-Point Participants' Raw Rating Responses from Post-Experiment Survey

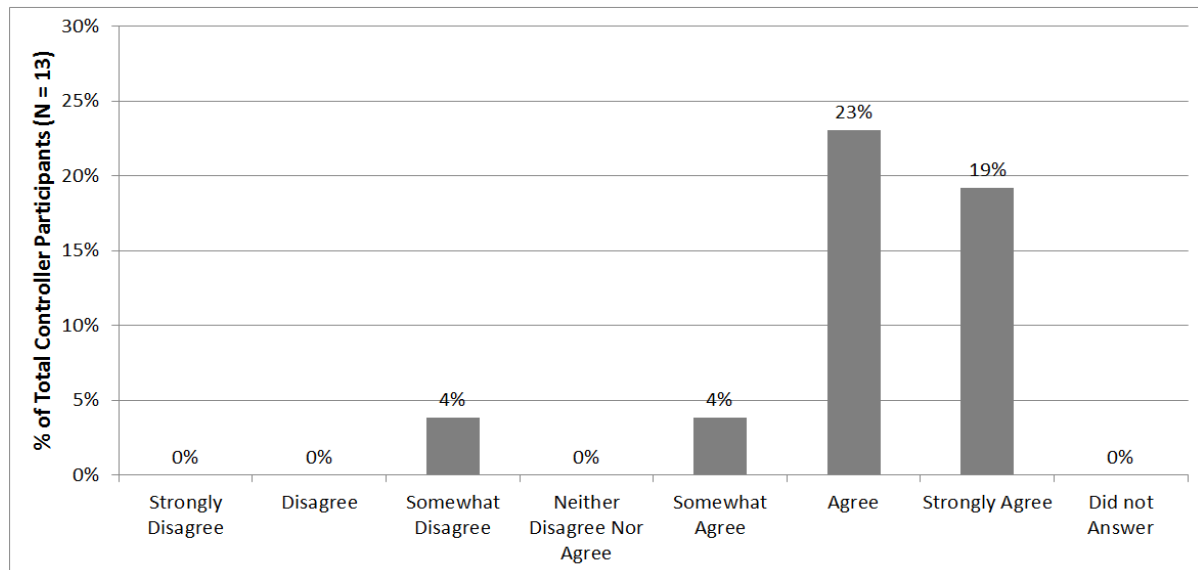


Figure I-1: Controller participant's self-assessed 7-point rating on whether participants feel comfortable with the online communication implementation

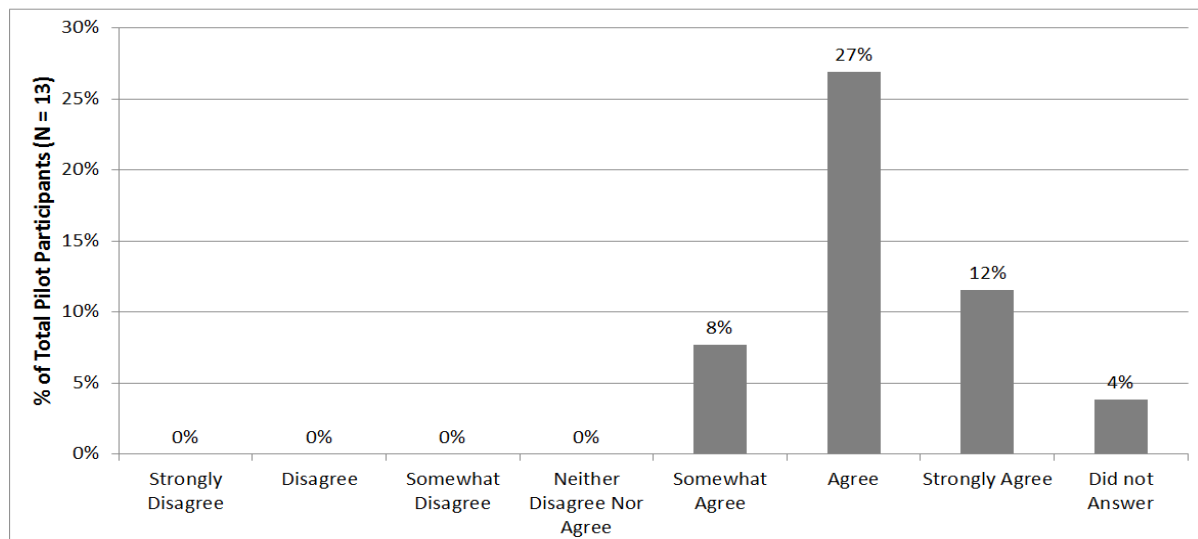


Figure I-2: Pilot participant's self-assessed 7-point rating on whether participants feel comfortable with the online communication implementation

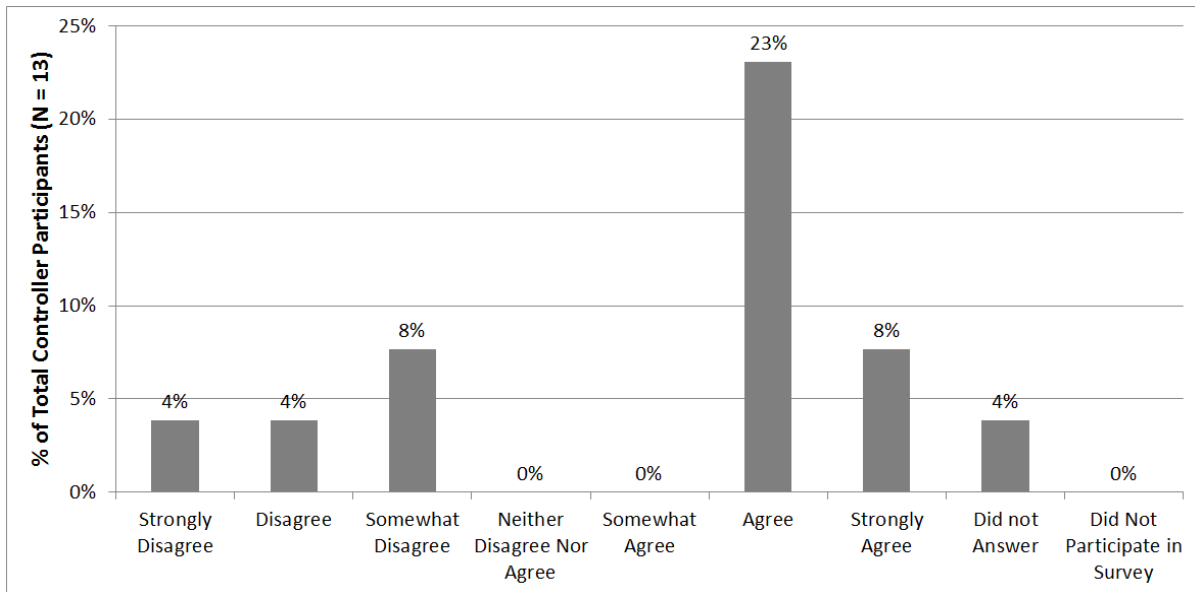


Figure I-3: Controller participant’s self-assessed 7-point rating on whether participants feel comfortable with the video-only simulator implementation

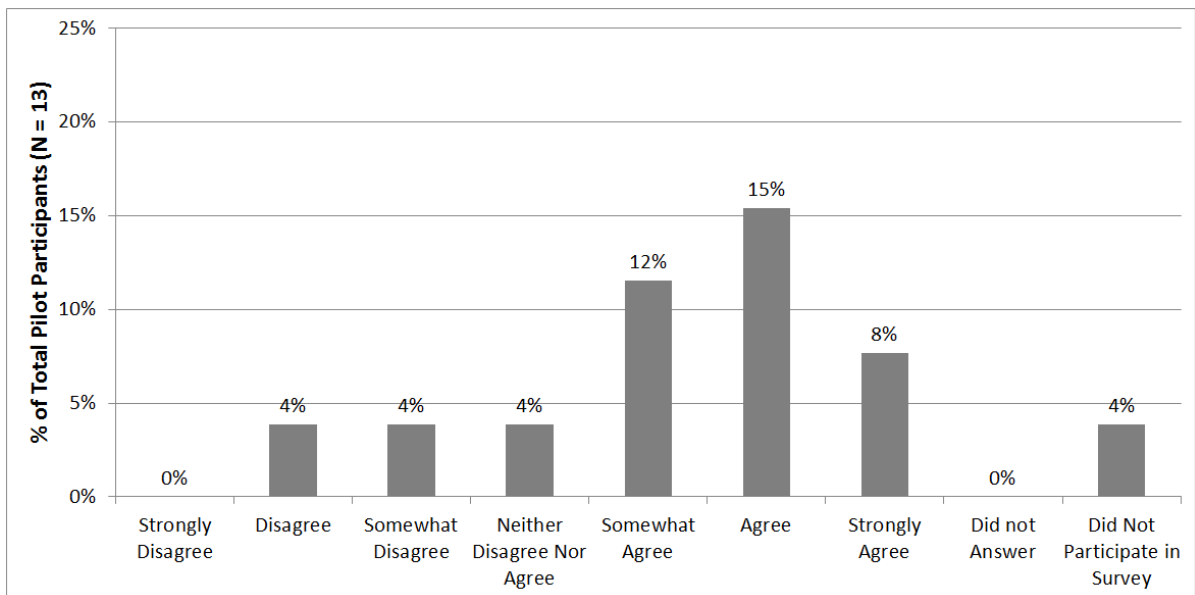


Figure I-4: Pilot participant’s self-assessed 7-point rating on whether participants feel comfortable with the video-only simulator implementation

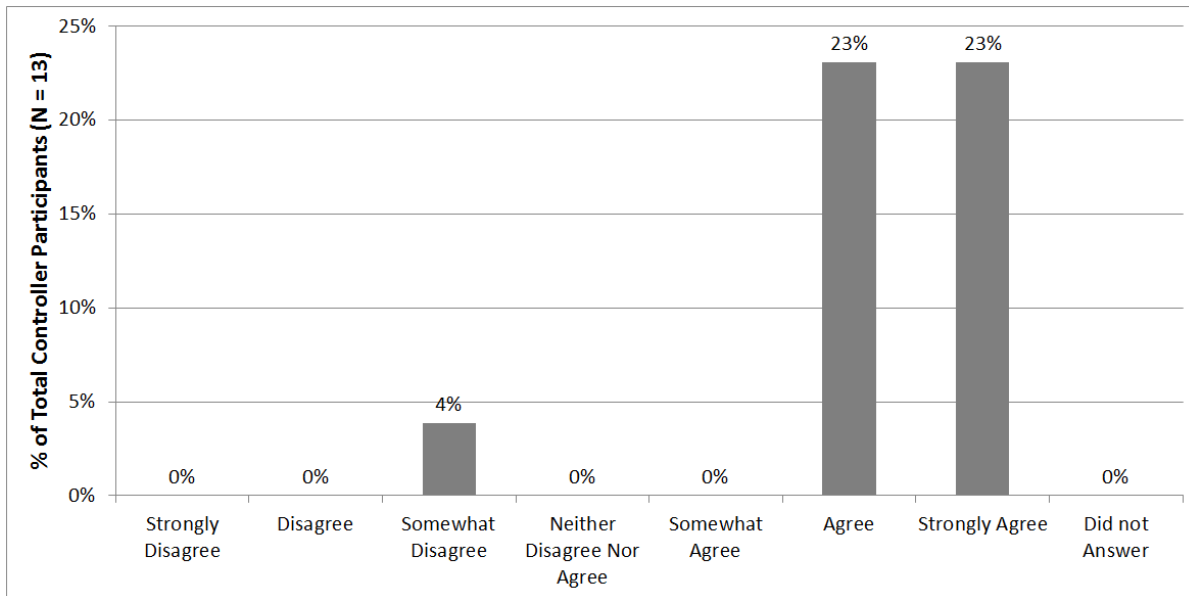


Figure I-5: Controller participant's self-assessed rating on whether participants feel comfortable with the online recruitment process

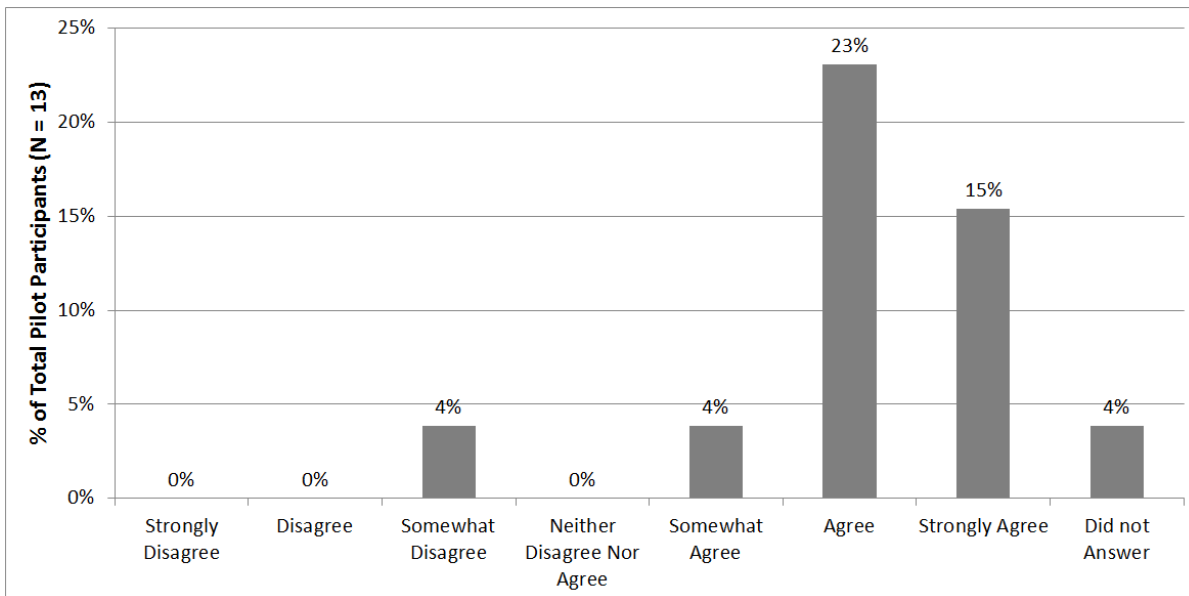


Figure I-6: Pilot participant's self-assessed rating on whether participants feel comfortable with the online recruitment process

Appendix J

Description of Coding Themes in Coding Analysis

Table J-1: Theme description for coding analysis as presented in Table 6-2: Participant suggestions to make future participants feel more comfortable with the online communication implementation

Theme	Description
Familiarize with technology	Suggest telling participants beforehand what technology to familiarize with prior to setting up online conference.
Better communication etiquette	Watch for etiquette details such as hot mic and speak slowly.

Table J-2: Theme description for coding analysis as presented in Table 6-3: Participant suggestions to make future participants feel more comfortable with the video-only simulator implementation

Theme	Description
Provide direct input control of simulator for participants	Direct participant-simulator input implementation both for controllers and pilots, instead of through experimenter putting in the input in response to voice commands.
Improve on display presentation issues	Cosmetic details of the displays, such as symbology should be bigger, colouring of lines, etc.
More comprehensive training for the video-only simulator environment	Participants wanted more and detailed training to prepare for the video-only simulator environment. This included a video of how simulator works, clarification of questions and more detail in the technologies used.

Table J-3: Theme description for coding analysis as presented in Table 6-4: Participant suggestions to make future participants feel more comfortable with the online recruitment process

Theme	Description
More comprehensive briefing and preparation for simulator session	Participants wants to be better briefed and prepared for simulator session in terms of more material, clarification and training
Trust issue	Difficulty of trusting the legitimacy of the researcher in terms of academic reputation vs fraud, as well as fear of uncertainty whether experience will be positive or negative

Appendix K

Time Delays and Traffic Configurations Used in Scenario

The table below shows the trial assignment used for this study. Each package (PKG) denotes the set formal trials experienced by a participant-pair. For each trial, the number - letter in the first column (i.e. 6C) denotes 6 seconds applied to controller side. The number in the second column denotes that traffic configuration 4 was used.

Table K-1: Trial assignment used for the follow-up study

	Trial 1		Trial 2		Trial 3		Trial 4		Trial 5		Trial 6		Trial 7		Trial 8		Trial 9	
PKG1	6C	4	6P	5	96P	2	48P	10	12P	8	12C	9	96C	3	48C	1	0	6
PKG2	0	8	48P	2	12P	1	6P	3	96C	6	12C	9	96P	4	6C	7	48C	10
PKG3	96P	5	6C	3	96C	8	48P	7	6P	6	0	1	12C	9	48C	10	12P	4
PKG4	48C	10	96P	1	6C	8	12P	4	0	7	96C	2	12C	9	48C	3	6P	5
PKG5	48P	10	96P	3	6P	9	12C	7	0	8	96C	5	48C	1	12P	6	6C	4
PKG6	48P	9	12P	2	6C	4	96C	3	96P	8	0	1	48C	6	6P	7	12C	10
PKG7	6C	7	0	1	12C	10	96C	8	6P	4	48P	6	48C	2	96P	5	12P	3
PKG8	96C	9	0	6	6P	2	96P	8	12C	1	48P	4	12P	7	48C	3	6C	10
PKG9	12C	3	48P	1	96C	7	6P	9	96P	10	12P	4	6C	2	0	6	48C	5
PKG10	0	3	12P	2	6P	10	6C	7	96C	9	96P	1	48P	4	12C	8	48C	5
PKG11	96P	4	6C	3	48C	10	48P	2	96C	1	12C	6	12P	9	6P	7	0	5
PKG12	6C	2	12P	6	96P	3	48P	7	6P	5	96C	4	48C	8	0	1	12C	9
PKG13	12C	5	6P	6	96C	2	0	8	6C	3	48P	4	48C	1	12P	10	96P	9

Appendix L

Module Codes for “Document Delivery Module”

```
<%@ Page Title="" Language="C#" MasterPageFile="~/Site.Master" AutoEventWireup="true"
CodeBehind="InfoAsynchStudy_Document_Delivery_Module.aspx.cs"
Inherits="IDEA.InfoAsynchStudy_PreExperimentQuestionnaire_Page" %>

<asp:Content ID="Content1" ContentPlaceHolderID="HeadContent" runat="server">
  <script src="http://ajax.googleapis.com/ajax/libs/jquery/1.6.2/jquery.min.js" charset="utf-8"></script>
</asp:Content>

<asp:Content ID="Content2" ContentPlaceHolderID="MainContent" runat="server">

<!DOCTYPE html>

<html>
<head>
  <title></title>
</head>
<body>
  <table>
    <tr>
      <td class="auto-style1">
        <p style="height: 49px; width: 579px;"><font size="6"><strong>Preliminary
Survey</strong></font></p>
      </td>
    </tr>
  </table>
  <hr />

  <p></p>

<!--For <td> styling for button and button itself-->
<style>
  td.SysVer-button {text-align: left}
  td.radio-button {text-align: center;}
  input[id=NextPage] {font-size: 1%; width: 13em; height: 30em}
  embed {
    border: medium;
    border-color: blue;
  }
  .auto-style1 {
    width: 504px;
  }
  .fwdarrow {
    background-image: url(images/ButtonFwdArrow.png);
    background-size: auto;
    background-repeat: no-repeat;
    background-position: center right;
```

```

padding-right: 50px;
vertical-align: middle;
}
.auto-style2 {
width: 2px;
}
.auto-style3 {
width: 501px;
}
}
</style>

```

<p style="font-size: medium;">Please refresh this page if the survey fails to load.</p>

<!--Fluidsurvey Embed Code. You can use either iFrame version or Embed version-->

```

/*<iframe id="fs-survey-iframe" src="http://fluidsurveys.com/surveys/liensamuel/test-questionnaire/"
style="border:2px solid #ccc;padding:2px; zoom:1; width:950px; height:400px"></iframe>*/

```

```

<script type="text/javascript" src="//fluidsurveys.com/media/static/embed-
helper.js">{"url":"//fluidsurveys.com/api/v3/embeds/"}</script><div class="fs-embed" data-
token="eyJ1c2VyIjoyMTI3Mjc4NDY4LCJpZCI6MjQ4MH0.8vg_rvu0008npDJ_hAn65gkxs8A"><div
class="footer">powered by <a
href="http://fluidsurveys.com/?utm_source=fluidsurveys&utm_campaign=powered-
by&utm_medium=embeds" target="_blank"><span
class="highlight">FluidSurveys</span></a></div></div>

```

<!--HTML Page Buttons-->

```

<asp:Button ID="ToSSSSButton" runat="server" class="fwdarrow" style="float: right" Text="To Next Page"
Width="325px" Height="35"PostBackUrl="~/InfoAsynchStudy_Test_Page.aspx" />

```

```

</body>
</html>
</asp:Content>

```


Appendix M

Windows Internet Information Service (ISS) Demonstration

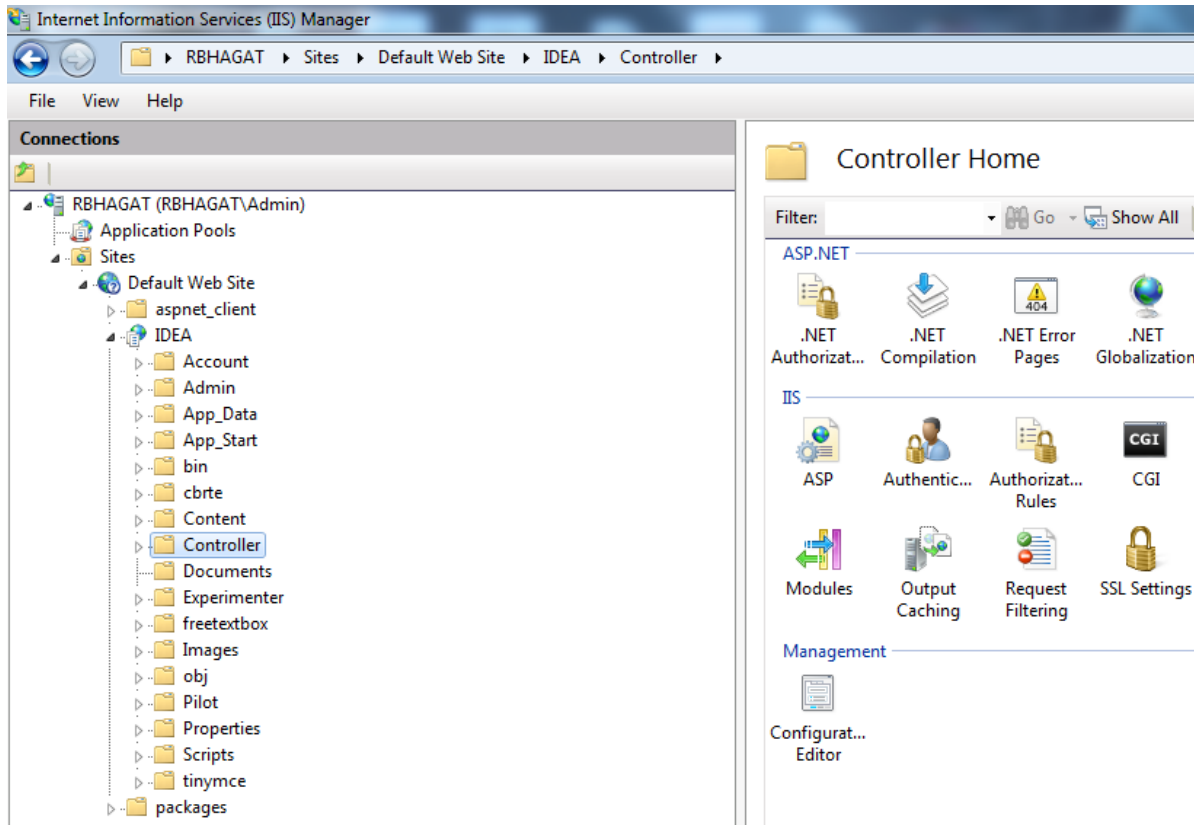


Figure M-1: Module code package hosted on the web through Windows ISS