Augmenting Process Elicitation with Visual Priming: An Empirical Exploration of User Behaviour and Modelling Outcomes

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Abstract

Business process models have become an effective way of examining business practices to identify areas for improvement. While common information gathering approaches are generally efficacious, they can be quite time consuming and have the risk of developing inaccuracies when information is forgotten or incorrectly interpreted by analysts. In this study, the potential of a role-playing approach to process elicitation and specification has been examined. This method allows stakeholders to enter a virtual world and role-play actions similarly to how they would in reality. As actions are completed, a model is automatically developed, removing the need for stakeholders to learn and understand a modelling grammar. An empirical investigation comparing both the modelling outputs and participant behaviour of this virtual world role-play elicitor with an S-BPM process modelling tool found that while the modelling approaches of the two groups varied greatly, the virtual world elicitor may not only improve both the number of individual process task steps remembered and the correctness of task ordering, but also provide a reduction in the time required for stakeholders to model a process view.

Keywords: Business Process Management, Process Elicitation, Subject-oriented Business Process Management, 3D Virtual Worlds, Human-computer Interaction

1. Introduction

Expert knowledge elicitation has for many years been a problem of much significance within a wide range of fields [12]. Tasks ranging from software requirements elicitation to graphic design all require an accurate flow of information between developers and end users. The inaccurate communication of this information has the potential to manifest in a variety of ways [46], including extended development times, higher construction costs or irrelevant products.

While each of these fields do not necessarily use the same exact approaches to elicit this information, the same general concepts and approaches are implemented. This usually involves having users attempt to articulate their requirements either verbally or technically, or using an observational approach, to have analysts better understand the client perspective and the exact requirements for the task in question [12]. These elicitation approaches, however, do not always provide accurate and succinct information. While the end users may be able to visualise their exact requirements, it is common that they are not able to fully express them correctly [4]. This may be caused by assumptions that end users believe are universally understood, despite them not being explicitly stated to developers [11]. This work attempts to address this issue by considering a novel approach to elicitation within the domain of Business Process Management (BPM).

BPM is an organizational approach which is commonly used to better formalise, analyse and optimise core business practices [42]. To achieve this, formal process models are constructed which must accurately describe all possible ways core business tasks may be completed. A single execution of a process is known as a *process instance*, with core business processes usually consisting of many concurrent process instances. Periodic analysis of aggregated process instances is used to identify issues which may arise within these models [42]. These models can then be adjusted when issues are detected to either mitigate, or eliminate, problem components. In 2014, a survey of 297 BPM-enabled companies found that 46% were spending upwards of half a million dollars annually on the methodology [26]. As accurate models are critical for business analysis and refinement [47], incorrect models can result in large amounts of wasted spending within an organisation.

The benefit of evaluating role-playing as an elicitation approach within the domain of BPM is that the accurate specification of task information is critical to the overall methodology [23]. The fundamental reliance on modelling languages to express complex behaviour has led to an abundance of literature examining the suitability of these languages [51, 44]. Despite this, however, very little research has examined how better elicitation with process stakeholders may improve the quality of the constructed models [10, 20]. Process mining is one alternate approach to process discovery commonly employed in BPM, but requires existing data logs and is restricted to primarily digital tasks [15]. Unfortunately, as many processes still involve core physical or spatial elements [50], process mining alone cannot always develop accurate models and must instead be supplemented with stakeholder elicitation [9]. This work aims to emphasize that while a robust modelling language is important, accurate stakeholder elicitation is paramount in the construction of quality process models.

1.1. Research Questions and Goals

In this study, a novel approach for eliciting expert information has been explored within the domain of process elicitation. Rather than have stakeholders try and verbally explain all of the various steps involved in a large task, they instead specify this information with a role-playing approach. To facilitate this, a 3D virtual world has been developed which closely mirrors the process execution environment of the stakeholder. The stakeholder must then traverse the world, role-playing each of the tasks which may be needed for correct execution of the process. As this is done, the tool captures the communication and tasks performed as well as their sequence and other flow structures (such as conditions) to build a formal specification. Figure 1 shows a virtual world resembling an airport. This example is used for the study at hand.

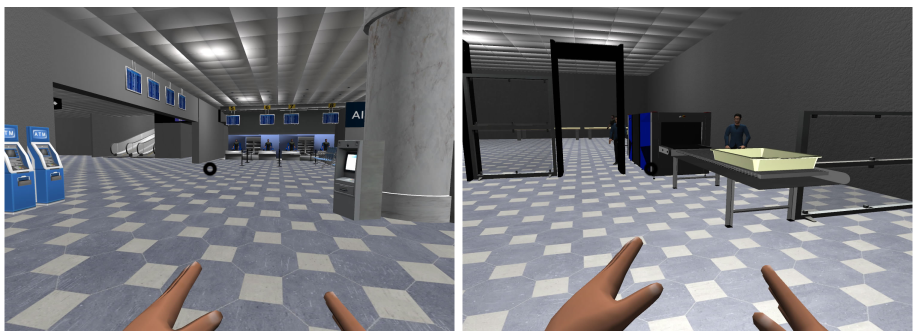

Figure 1: Screen captures of the virtual world airport scene.

The goal of this approach is to place experts into a more familiar environment during task specification. In doing this, there is also the potential to achieve a perceptual priming response [36], thereby adjusting cognitive processes to better assist with memory recollection. There are two broad research questions which will be investigated in this paper:

RQ1: What are the differences in *process modelling outputs* between those who use the virtual world role-play tool, and those who use a regular process modelling tool?

RQ2: What are the differences in the *process modelling approach* between those who use the virtual world role-play tool, and those who a regular process modelling tool?

An initial investigation of this virtual world elicitation approach [24] focused solely on exploring the first research question above. This paper, however, will extend this work significantly and also explore differences in the modelling approach between those who use a virtual world to specify tasks and those who use a more standard process modeller. Modelling behaviours have been explored in this paper as prior research has shown a compelling relationship between the way in which users construct their models, and the quality of the final outputs [10]. Until now, observation of this phenomenon has been limited to elicitation using standard, non-immersive, modelling tools. By analysing modelling behaviour of participants given the virtual world modelling tool, we aim to better understand how participants choose to construct their models and whether or not a similar relationship between behaviour and model quality can be observed.

Existing theory has allowed for the formation of three main hypotheses surrounding the first research question (Sections 2 & 5), but competing theories related to user behaviour prevent concrete hypotheses from being developed for the second research question. Specifically, existing process of process modelling theory suggests that users who construct their models faster are more likely to have quality models [10] while virtual world theory would suggest the time the user spends in the environment may relate very little to their understanding of the task, and instead to how they interact with the world [28]. Accounting for this, model construction metrics applied previously in process of process modelling analyses, such as how users spend their modelling time, have been investigated as these have been shown to be accurate predictors of expected model quality [10].

It must be noted, however, that the elicitation approach explored in this work still requires further development. Standard process elicitation is usually completed in a collaborative setting, whereby several parties communicate to construct an overall understanding of a task. This paper, however, describes an elicitation approach which uses only a single participant and therefore has no person-to-person interactions. This has been done to better explore how the virtual world priming may affect procedural knowledge recall. If this work was to be applied in a true ecological setting, however, this approach would be extended to allow for multiple stakeholders to each role-play their specific tasks, interacting with both the environment and other users within the virtual space. This will require further work, however, to evaluate the overall efficacy of such an approach. Instead, this paper will be limited to furthering current understanding of how virtual world interactive priming may influence user memory and behaviour within a process elicitation setting.

1.2. Research Methodology and Contribution

To evaluate this role-play elicitation methodology, a tool using this role-playing approach has been constructed which utilizes the subject-oriented business process management (S-BPM) modelling grammar [18]. The S-BPM grammar has been chosen for this work as it describes processes by linking several viewpoints, or *subject-views*, instead of a single overall model (described further in Section 3 below). As each of these subject-views encapsulates the internal behaviour of a single entity, using a role-play approach is believed to be an effective way of eliciting this information. The efficacy of this new virtual world approach has been evaluated using the build-evaluate design science methodology [1]. This evaluation has been done in the form of an A/B comparative experiment, comparing the virtual world with a custom S-BPM process modeller also developed in this work. The experiment goal was to evaluate the ability of participants to accurately recall and structure a series of process tasks while also exploring the way in which users interact with the world to construct process models. This has been compared with a more standard process modelling approach in order to identify any major differences in both the modelling approach and the final model outputs.

While the benefit of this approach has been described specifically with regards to its application in process elicitation, the outcomes have relevance to several domains. This work is predominantly motivated by existing priming theory and, to our knowledge, no existing work has thoroughly explored the potential of using virtual worlds to prime episodic memory recall. Furthermore, if this approach does allow users to recall more information within the scope of process modelling, the results would likely generalise to a range of other elicitation settings which rely heavily on user recall.

1.3. Structure

Section 2 will examine virtual worlds and their current application in semantic priming and episodic memory recall. Section 3 will examine the S-BPM language, particularly the individual subject views, as the virtual world currently generates outputs using this grammar. Section 4 outlines the features of the developed virtual world, with a focus on how users interact with the environment to complete tasks. Section 5 provides an overview of the experiment design, including hypotheses and overall approach. Section 6 provides results and Section 7 analyses the significance of these results and whether they match original predictions. Section 8 considers the limitations of these findings in addition to any potential threats to validity. Section 9 considers similar research which has previously been conducted in this area. Finally, Section 10 will conclude by summarising areas of interest and identifying the logical next steps to further evaluate this approach.

2. Virtual Worlds and Cognition

Our elicitation approach, and related tool, borrows heavily from a number of areas in psychology related to memory recall. In order to establish the main theoretical bases for this research, we must look to established work in the psychological topics of *Semantic Priming* and *Episodic Memory Recall* to inform our design decisions in both our elicitation tool and our experimental methodology.

2.1. Semantic Priming

Fundamental theory motivating this research is drawn from the effect of priming by interactive visual stimuli. Priming can be seen as the modulation of internal brain activation in a person via stimuli that induces a modification in later behaviour [5]. More specifically, semantic priming involves the stimuli being from similar semantic categories that have shared features [17]. Semantic priming is theorized to work because of the non-local effects of stimuli activations in the brain [40]. When a person thinks of one item in a category, similar items are stimulated along related neural networks. Thus, a person's brain, upon being presented with stimuli such as the word “France,” is likely to stimulate later related responses such as “Paris”. A number of studies have examined the concept of visual priming in detail with stimuli from television [27] and briefly flashed and masked images [32] amongst others.

Research has been conducted into the use of virtual reality priming for theoretical development purposes [36], and for psychological applications, such as mental trauma treatment [14]. Closer to the research in this paper, investigations have been performed into the use of priming in virtual worlds to guide users to select terms in conversations with 3D avatars [38]. Specifically, they found that in a virtual reality setting, keywords from selected sets were chosen more regularly when priming images were presented in a virtual world during a conversation with an avatar. Thus we see a very specific focusing effect on the selection of words in conversations in the virtual world via this visual priming process. This priming of specific keywords within virtual worlds is the motivating theory informing the development of Hypothesis 1(c), which hypothesises that users primed by the virtual world will be more consistent with their naming. The individual descriptions for process steps can be considered to be a series of required keywords. If these keywords appear more frequently when given perceptual priming stimuli, the virtual environment should result in more consistent naming across a group of participants.

2.2. Episodic Memory Recall

Episodic memory is the process where humans autobiographically remember events from previous experiences [45]. As a consensus, it appears that the hippocampus in humans mediates this episodic memory process, and a number of studies have used virtual reality to explore theoretical bases in brain activation [8], but there is an absence of definitive work regarding virtual reality effects on the veracity of episodic memory.

There is evidence of potential positive effects on memory recall with an increase in virtual reality fidelity and immersion [43], in particular on the experience of remembering. These effects are not positively correlated with an increase in immersion but in fact are positively correlated with a normal desktop virtual reality system. Thus the use of immersive forms of VR is not necessarily an improvement to the memory recall effects of participants. However, in contrast, there is related work on recall of sequences of embodied tasks in virtual worlds using immersive training videos that have been shown to aid memory recall of physical embodied actions [3].

We have previously theorized that the presentation of visual representations of stakeholder locations will stimulate episodic memories of the tasks being performed by a person in a workplace as a part of process modelling [21], but to date we are not aware of any research that empirically tests for improved elicitation of knowledge via virtual worlds. In particular, we do not know of any studies that seek to use virtual worlds to stimulate memory of past activities in process elicitation. We therefore hypothesise that the verbal feedback provided by the users of the virtual world will be primed by the visual stimuli, potentially bringing about a more focussed response, modulating the written responses of the participants in the study when performing their process modelling tasks. In addition, as per Roussou (2001) [43], a desktop virtual reality system will have a positive effect on episodic memory, leading to more accurate process models, reflected in Hypothesis 1. More details on the specific hypothesis development in this paper is found in Section 5.

3. The S-BPM Language - Fundamentals

Subject-oriented Business Process Management (S-BPM) [19] is a methodology that follows a decentralised approach to modelling and executing processes. In this approach, processes are understood as the interactions between process-centric roles (called *subjects*) where every subject has its own behaviour specification in terms of the actions executed by a process participant. The behaviours of different subjects are coordinated by the exchange of messages between subjects. Based on the strong emphasis on the role concept and on the communication between roles, S-BPM shares some similarities with Role-Activity Diagrams (RAD) [35], UML communication diagrams, and the DEMO methodology [13]. However, there are also a number of significant differences with respect to these approaches. For instance, S-BPM has rigorously defined execution semantics, allows asynchronous communication, and supports end-user involvement in process modelling. The latter is based on the encapsulation of behaviours in different subjects, and on the simplicity of the S-BPM modelling language.

The encapsulation concept in S-BPM enables modelling the behaviour of a subject without requiring knowledge of the behaviour of other subjects; only the messages exchanged with other subjects need to be known. Different subject behaviours can therefore be modelled independently of one another as long as the interfaces between them (i.e. the messages) are well defined. This allows different subject owners to model their behaviours in their own ways, based on their individual working styles and terms. Such a decentralised approach to modelling differs from traditional approaches that cast the behaviours of different process participants in a single, monolithic process model.

The language used in S-BPM has been designed to be very simple, allowing process participants to readily model their own behaviours without requiring extensive training in a formal modelling notation. It is based on natural language grammar that uses standard *subject-object-predicate* constructs. Subject behaviours are modelled by linking three possible states: *internal action*, *send* and *receive* [18]. Internal actions represent actions completed by the subject, while send and receive states represent communication between subjects. An example S-BPM subject view can be seen in Figure 2. Subject behaviour models are executable as they follow the semantics of Abstract State Machines [6]. The states in a subject behaviour definition are strictly sequential. Parallelism is represented using separate subject behaviours.

The S-BPM language has been chosen as it provides concise mapping between first-person virtual world actions and S-BPM model components without requiring participants to model the process from a global viewpoint.

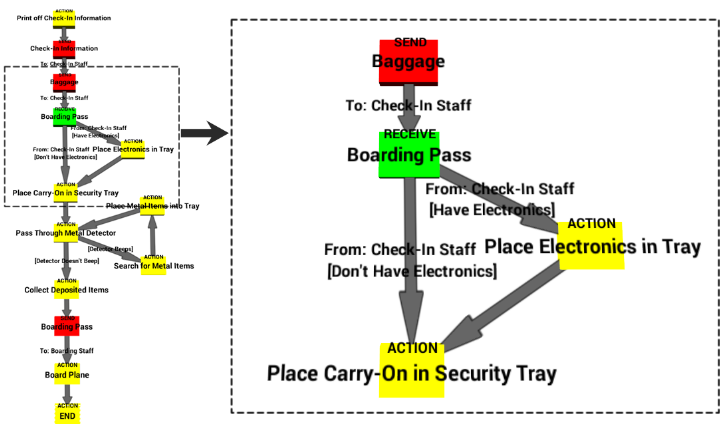

Figure 2: Complete S-BPM Subject-View Model for the Experiment Task. The left diagram displays a complete base model for the experimental case, with the right diagram showing a blown-up version of the dotted area.

It should be noted that while the S-BPM language is believed to be the best fit for this particular elicitation approach, it does not mean that other modelling languages could not also map to virtual world actions. Work has been done investigating the possibility of producing a BPMN model from subjective viewpoints [29]. There is even potential for this world to output models of varying languages, as object interactions can be mapped in a largely language independent manner.

4. Virtual World Implementation

Virtual worlds are synthetic environments which provide users with an avatar through which they can interact with other users, or interact with the world itself to perform specified tasks [16]. Virtual world research is extremely broad, examining potential in a number of fields including education, training and simulation [28]. A major issue in virtual world research, however, is that many of these worlds can be difficult to use without extensive training [48]. With this in mind, the features of the virtual world were carefully considered, with a user design experiment previously being conducted to evaluate tool usability [25].

4.1. Construction Overview

The virtual world used in this work has been constructed using the Unity3D[1] game engine with the environments containing a mix of both modelled and pre-built assets. The user is given an avatar through which they can traverse the world to interact with objects, as this is a core component for a role-playing

[1]Unity3D: www.unity3d.com, accessed: November, 2014

approach to process elicitation. The world used in this study has been constructed with a high degree of fidelity, including both high quality assets as well as objects which do not necessarily have core importance to process execution, despite previous work indicating that they do not meaningfully affect user priming in these environments [22]. The reasoning behind this choice is that while the walls of a building and other objects may be superfluous for priming memory, they are still critical for role-playing a process naturally. Furthermore, easy access to recent 3D asset banks such as *Unity Asset Store*[2] or *3D Sketchup Warehouse*[3] has allowed the environments used in this study to be developed within a matter of hours. In this experiment, the environment has been manually developed in order to allow for very structured interactions. This makes the experience somewhat easier for the user, but also requires a certain level of conceptual understanding of the task requirements. If this approach was adapted for elicitation within an ecological setting, it may also be more appropriate to use depth-camera technology (such as the *Matterport*[4]) to accurately construct 3D models via scans of real-world spaces. This removes the need for a developer to determine which items are and are not important to the virtual space. As all items are present, users are free to interact with any part of the scene (assuming the necessary items were located within the space at the time of initial scanning).

4.2. Scene Interactions

The core concept with this role-playing elicitation approach is that users should be able to naturally traverse the environment and interact with objects similarly to how they would in reality. In the developed virtual world, almost all objects have this interaction capability, with the only notable exceptions being walls, floors or other objects which have no standard interactions. To interact with an object, users simply click on the object they wish to use. This will produce a list of common generic actions or allow the user to create an entirely new one if necessary. By providing a list of structured generic options, user commands are tagged, thereby providing additional structure to their responses and allowing for better categorisation and merging of different process views. This is particularly beneficial when working with view-based models as views are often merged by searching for matching strings [7]. After the user has selected their chosen generic action, they will be prompted to enter a more comprehensive explanation of the specific task being performed. Figure 3 shows each of these steps in detail, with a corresponding task output. After the user has finished performing an interaction, the system will construct an S-BPM model which matches the actions which have been completed to that point.

[2] Unity Asset Store: www.assetstore.unity3d.com, accessed: November, 2014
[3] 3D Sketchup Warehouse: 3dwarehouse.sketchup.com, accessed: November, 2014
[4] Matterport: www.matterport.com, accessed: January 2016

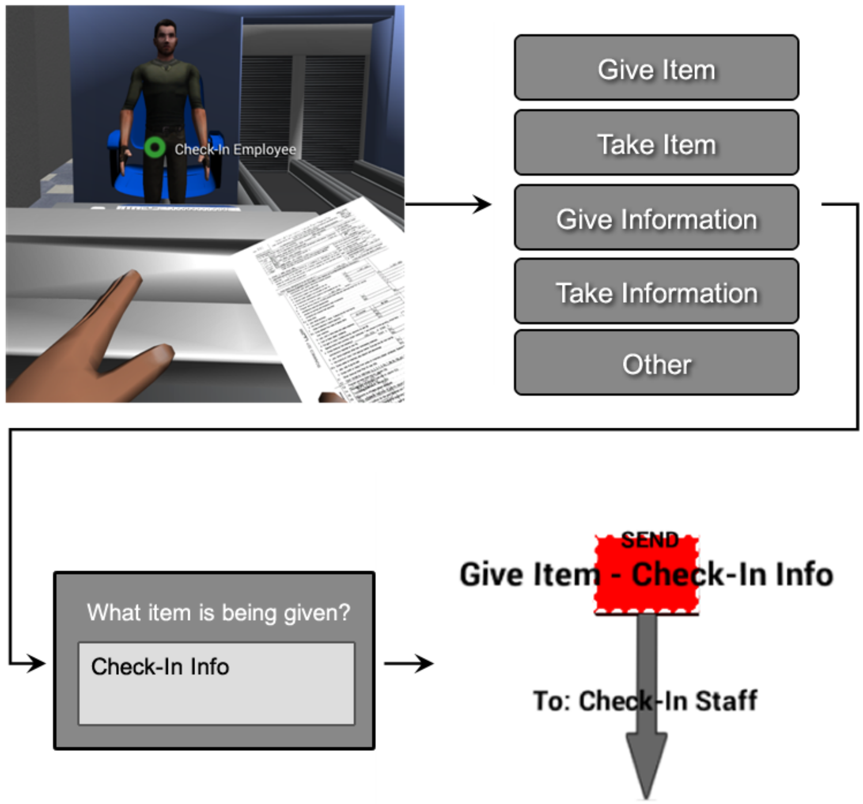

Figure 3: Virtual world commands required to specify the handing of check-in information to airline staff.

5. Experiment Outline

The experiment conducted in this study aimed to identify differences in process model outputs and modelling methods between participants who use the virtual world to construct models, and participants who use a standard grammar-based modelling approach. The custom S-BPM modelling tool shown in Figure 2 was used for the comparison case in this experiment. This S-BPM modelling tool was also developed specifically for this experiment and forgoes advanced workflow features not required for the task in order to make core features more accessible. Furthermore, as the two tools were designed specifically for this experiment, they use the same underlying engine, a similar set of controls, and many homogeneous user interface items (e.g. dialogue boxes, buttons, panels) which include identical font types, color schemes and icon images.

Participants for this study were randomly sourced from students at the Queensland University of Technology, Australia. University students were considered an appropriate sample for this initial study as they were expected to have a similar level of airport process understanding to that of the wider population.

Each participant was randomly assigned to one of the two study conditions. In this experiment, one structured research question and one exploratory research question were examined.

5.1. Hypotheses and Research Questions

The first hypothesis of this study was that *participants working in the virtual world would specify more robust process models than those working with the S-BPM process modelling tool.* This hypothesis directly relates to the first research question and has been split into three measurable sub-hypotheses:

1a) Participants using the virtual world role-play tool will correctly specify a larger number of task steps than those using the S-BPM process modelling tool.

1b) Participants using the virtual world role-play tool will specify fewer erroneous task sequences than the those using the S-BPM process modelling tool.

1c) Participants using the virtual world role-play tool will be more consistent with their naming than those using the S-BPM process modelling tool.

The theory for Hypotheses 1(a) and 1(b) has been discussed in Section 2.2 above. Use of desktop virtual environments has been shown to have positive benefits on episodic procedural memory [43]. As process elicitation is a complex form of episodic recall, it is believed that this effect should translate to better recall within the context of process modelling. The theory for Hypothesis 1(c) has been discussed in Section 2.1 above. Prior investigation has shown that immersive virtual environments can prime users to communicate with specific keywords [38]. As process models are described with a series of keywords, users should become more consistent with their naming when this priming is present. Consistent naming within process models is considered to be a characteristic of robust models as it allows for easier correlation of similar actions [18].

The second hypothesis of interest in this study was that *participants in the virtual world would be more confident in their actions than those working with the S-BPM process modelling tool.* This hypothesis relates to the second research question and has been measured using two sub-hypotheses:

2a) Participants using the virtual world role-play tool will make fewer model alterations than those using the S-BPM process modelling tool.

2b) Participants using the virtual world role-play tool will be more confident in their performance than those using the S-BPM process modelling tool.

There are several pieces of literature which support this hypothesis. Users in the virtual world may exhibit greater confidence as they can better visualise their actions [41] or because they were simply more engaged with the task [49]. If the first hypothesis holds true, however, better confidence may simply result from better recall. To better understand this effect, both an objective measure (model alterations) and a subjective measure (performance self-assessment score) have been considered.

Finally, this study also aims to investigate an exploratory research question, specifically: *What are the differences in the process modelling approach between those who use the virtual world role-play tool, and those who use the S-BPM process modelling tool?* While we fully believed that the two tools were likely to have many differences, there was competing literature, both theoretical and empirical, in this area to allow for strong hypotheses to be developed. Instead, many common modelling measures have been considered including the time to complete the model and the way in which items were added, edited or removed [10].

5.2. Experiment Procedure

Participants who agreed to participate in the study were invited into a lab and presented with a keyboard, mouse and 24" monitor. Upon arrival, they were randomly assigned to one of the two test cases and provided with basic training in the form of an annotated video. As both tools required different forms of training, however, this difference needed to be controlled. This was done by ensuring both videos had the exact same play length (four minutes) and covered identical topics. Furthermore, a 7-point Likert-scale item was included in the questionnaire at the end of the experiment which asked participants to rate how well they believed they had been trained for the task to further control for any differences which may have existed in the training videos. This test identified no statistical difference between users given the virtual world video (M = 5.44, SE = 0.51) and users given the S-BPM process modelling video (M = 5.60, SE = 0.22), $t(62) = -0.16$, $p = 0.1083$.

For this experiment, participants used their assigned tool to describe all of the actions which may be necessary in boarding an airplane for a short domestic flight. To limit the scope of potential responses, participants were asked to only consider tasks occurring after they had already arrived at the airport and before they boarded the plane. This task was specifically chosen to evaluate this approach as it includes several spatially seperated physical actions. If the task was instead information-centric, other novel elicitation techniques such as a modified role-play or process mining approach may instead prove to be more effective at eliciting information.

To assist in standardising knowledge of the process, participants were given a series of real world images showing each of the core steps involved in the process alongside textual descriptions of the corresponding actions. This task normalization technique has been used successfully in other studies that examine the ability of a stakeholder to model a task [39]. Examples of described tasks include:

- Collecting a Boarding Pass
- Handing Baggage to Airport Check-In Staff
- Placing Carry-On Luggage into Security Trays

It should be noted, however, that this standardisation would likely not be needed when working with expert stakeholders. This standardisation has been applied in this experiment as most participants, despite being familiar with the airport boarding task, would not be considered true airport boarding experts. To determine whether participants were only recalling the original task description, or instead recalling from past experiences, participants were also asked to include any *additional* tasks (without removing or reordering existing steps) that they would normally complete during the process. This was done to better identify whether participants were primed by past experience in the process, or simply by the task description they had been given.

6. Results

Participants were randomly assigned to one of the two conditions, with each condition having 32 participants. The average age of this cohort was 21.2 (SD = 2.9), with a gender distribution of 45 males and 19 females. The level of prior process modelling knowledge was quite low, with an average response of 1.9 on a seven-point Likert scale (SD = 1.27). Perceived understanding of the airport boarding process was quite high, with an average response of 5.2 (SD = 1.4). Of the 64 respondents, 38 reported that they had boarded an airplane sometime during the year. Finally, participants in the virtual world reported moderate virtual world exposure, with an average response of 4.3 (SD = 2.4). A complete breakdown of salient control question scores for both treatments can be seen in Table 1 below.

Table 1: Salient Control Values by Treatment Case

	Virtual World Role-play Tool	Process Modelling Tool
Gender	24 Males, 8 Females	21 Males, 11 Females
Age	M = 21.44, SD = 2.78	M = 21.00, SD = 3.05
Task Experience	M = 5.25, SD = 1.52	M = 5.22, SD = 1.24
Modelling Experience	M = 1.78, SD = 1.22	M = 2.02, SD = 1.31

As none of these control scores indicate any statistically significant differences between the two treatments (all tested p values > 0.4), fair comparisons can be made between the two groups. As multiple tests of significance have been performed below, a Bonferonni correction has been applied to keep the family-wise error rate to 0.05. In total, 10 individual univariate tests were performed with a revised significance level of 0.005.

6.1. Hypothesis 1: Participant Recall

The first hypothesis aimed to evaluate participant memory recall. Due to the complexity of measuring recall, however, three hypotheses were tested, relating to (a) the number of tasks remembered, (b) the number of task sequencing errors and (c) the consistency of words participants used to describe tasks.

Hypothesis 1(a): Tasks Remembered

Part (a) of Hypothesis 1 has been evaluated by analysing two factors: the number of base explanation steps recalled and the number of additional steps added. Results from these tests showed that participants in the virtual world remembered both a larger number of base tasks (M = 11.22, SE = 0.26) than those given the S-BPM process modeller (M = 9.03, SE = 0.31), $t(62) = 5.37$, $p < 0.0001$, r = 0.56 and a larger number of additional task steps (M = 2.19, SE = 0.32) than those given the S-BPM process modeller (M = 0.84, SE = 0.21), $t(62) = 3.54$, $p = 0.0008$, r = 0.41.

Hypothesis 1 (b): Task Ordering

Part (b) of Hypothesis 1 stated that participants using the virtual world role-play tool would specify fewer erroneous task sequences. To evaluate this hypothesis, the average number of incorrectly ordered tasks was considered. Results from this test showed that participants in the virtual world placed fewer tasks in an incorrect order (M = 0.19, SE = 0.07) than participants in the S-BPM process modelling tool (M = 0.72, SE = 0.16), $t(62) = 3.09$, $p = 0.0003$, r = 0.37.

Hypothesis 1 (c): Consistent Naming

Part (c) of Hypothesis 1 stated that participants in the virtual world would be more consistent with their naming. To evaluate this, the total number of distinct words used by participants has been examined, both as an absolute value and as a ratio of unique words to total words used. If the overall wording pool from participants contains fewer unique words, or words are reused more often, users are likely referring to actions and objects more consistently with their naming. Results from these tests show that participants in the virtual world used a smaller set of unique words to explain the process (M = 38.15, SE = 4.25) than those using the S-BPM process modelling tool (M = 67.92, SE = 5.11), $t(62) = 4.48$, $p < 0.0001$, r = 0.49. Comparing the percentage of unique to total worlds also shows a similar affect, with participants in the virtual world having much lower ratios (M = 0.24, SE = 0.01) than those in the S-BPM process modelling tool (M = 0.41, SE = 0.02), $t(62) = 7.38$, $p < 0.0001$, r = 0.68.

The results from this test indicate a noteworthy effect, with participants in the virtual world constraining their vocabulary more heavily than participants in the S-BPM process modelling tool. To verify that this result did impact on their task labelling, an analysis of frequent words has also been performed. The below table shows the two most common words (or phrases) used by participants to describe specific actions. This strongly suggests that the participants given the virtual world role-play tool were more consistent with their word usage than those given the S-PBM process modeller, e.g. Boarding Pass (49 in Virtual World Roleplay vs 28 in S-BPM Process Modeller). For each of the items listed below, no formal cue was provided within the virtual world to assist participants with their choice of words. The *Expected Name* corresponds with the wording given in the task description. These expected names were chosen as they were the most common phrases used during the pilot study.

Table 2: Most Frequent Word Choices by Treatment Case

Expected Name	Virtual World Role-play Tool	S-BPM Process Modelling Tool
Boarding Pass	Boarding Pass (49), Ticket (4)	Boarding Pass (28), Ticket (16)
Metal Items	Metal Items (11), Metal Objects (9)	Metal Items (4), Metallics (2)
Carry-On	Carry-On (19), Bag (8)	Bag (9), Carry-On (7)

This analysis shows that when referring to a specific object, participants in the virtual world more commonly used the same wording choices, while participants in the S-BPM process modelling tool had a much more evenly distributed spread of responses.

6.2. Hypothesis 2: Modelling Confidence

Hypothesis 2 stated that users in the virtual world would be more confident in their approach. This has been evaluated by analysing two main factors: (a) the number of alterations participants made to their models and (b) the subjective performance scores given by participants.

Hypothesis 2 (a): Model Alterations

Part (a) of Hypothesis 2 examines the number of times the participants altered their models. This may result in wording changes, task reordering or task deletions. For this analysis, the combined total of each of these values has been considered. The results of this test showed that participants in the S-BPM process modelling tool made more modifications to their model (M = 3.38, SE = 0.45) than those in the virtual world (M = 0.81, SE = 0.23), $t(62) = 5.10$, $p < 0.0001$, r = 0.54. This result is consistent with previous work, which found that higher model alterations was an indication of poor model quality [10].

Hypothesis 2 (b): Subjective Confidence Scores

After constructing their model, participants were asked to subjectively rate their performance. As no existing metrics for this could be found within area of the stakeholder elicitation, the performance measure used in the NASA-TLX workload questionnaire [33] was adapted for this purpose. This score ranged from 1 (subjective failure) to 7 (subjective perfect performance). This revealed participants were more confident in the virtual world (M = 6.25, SE = 0.19) than the S-BPM process modelling tool (M = 4.56, SE = 0.37), $t(62) = 0.62$, $p < 0.0001$. The results of Hypothesis 1, however, suggest that virtual world users *were* able to generate better models for this particular modelling session. To determine whether the higher confidence scores were simply due to better modelling, or instead due to differences in the modelling approach, Pearson correlation tests were performed. These tests compared the given subjective confidence scores with both the number of steps recalled, and the number of erroneous task sequences. This found no significant correlation between subjective confidence and tasks specified in either the virtual world (r = 0.11, n = 32, p = 0.55) or the S-BPM process modeller (r = 0.22, n = 32, p = 0.23). Similarly, no correlation was found between subjective confidence and sequencing errors in either the virtual world (r = 0.18, n = 32, p = 0.32) or the S-BPM process modeller (r = 0.30, n = 32, p = 0.10). As neither of these tests show a statistically significant correlation, however, it is unlikely that the higher virtual world confidence scores were solely a result of better modelling, and were instead due to differences in the overall modelling approach.

6.3. Exploratory Investigation of Modelling Approach

Unlike the first research question examined above, this section will instead investigate the second research question (the modelling construction approach of both groups) in a much more exploratory manner. In particular, (a) how participants used their modelling time and (b) the actions they performed will be examined.

Modelling Approach (a): Time Breakdown

The time required to complete the task has been examined as there are several factors that may affect this result. Semantic priming theory suggests that the virtual world may allow participants to recall actions faster, but prior virtual world research has identified that participants may also choose to explore these worlds instead of completing the assigned task. Comparing the average time (in seconds) participants took to construct their models showed that participants in the virtual world constructed their models faster (M = 377, SE = 30.80) than those in the S-BPM modelling tool (M = 668, SE = 57.41), $t(62) = 4.47$, $p < 0.0001$, r = 0.49. This result is once again consistent with previous work, which found that longer modelling times was an indication of poor model quality [10].

As this represents quite a large difference, further analysis has been performed to identify potentially contributing factors. Figure 4 shows a more detailed breakdown of where both groups spent their time during the modelling process. In the below graphs, participants were considered idle if they had gone at least 5 seconds without completing any other action. Furthermore, it should be noted that both groups have an item specific to their treatment. In the S-BPM process modelling case, participants were able to adjust the visual placement of items (a standard feature in most modelling and workflow tools). In the virtual world role-play treatment, participants were not able to view or modify the appearance of their model but instead spent time moving between the individual locations within the virtual world.

From the data gathered, it cannot be determined whether the users in the S-BPM process modelling case were task-oriented in their approach, or were

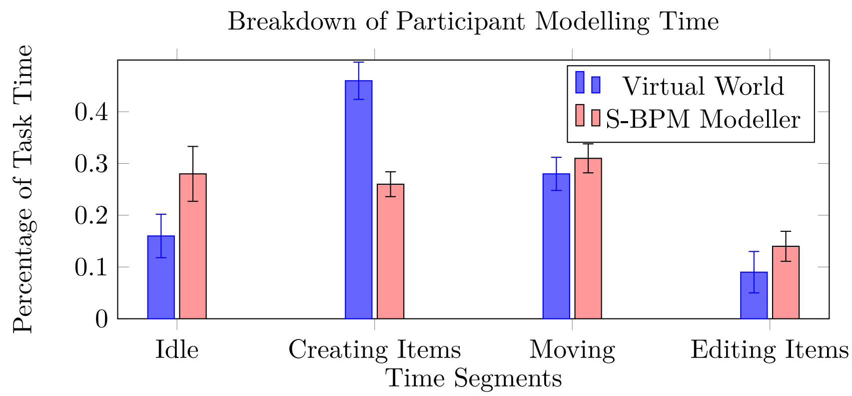

Figure 4: Virtual world role-play and S-BPM process modeller modelling time breakdown.

instead choosing to experiment with the tool they were given. Higher idle time may indicate that participants were trying to recall tasks, but may also indicate that the participant was not fully concentrating on building the model. It is possible, however, to gain insight about the task-oriented nature of participants in the virtual world. Figure 5 below shows a heatmap comparing user movements within the environment to the locations at which tasks were completed. If the users were exploring unnecessary parts of the environment, it may be an indicator that they were more interested in exploring the world than completing the task.

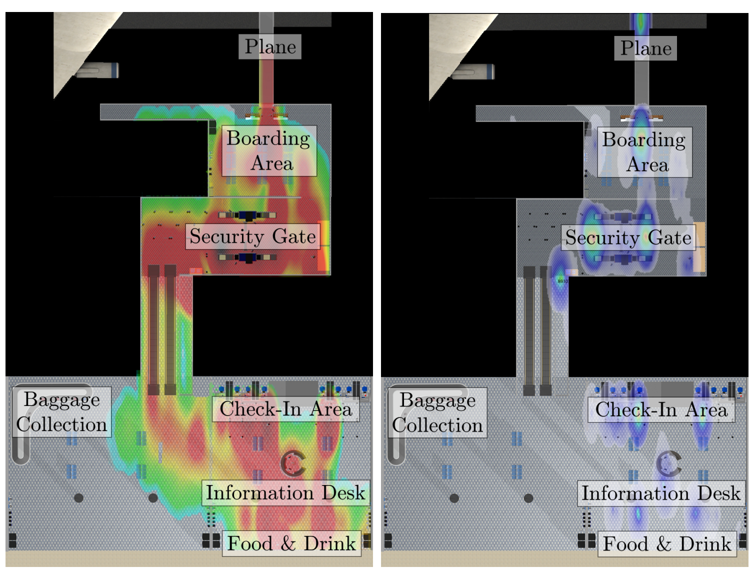

Figure 5: Heatmaps of virtual world movements (left) and actions completed (right).

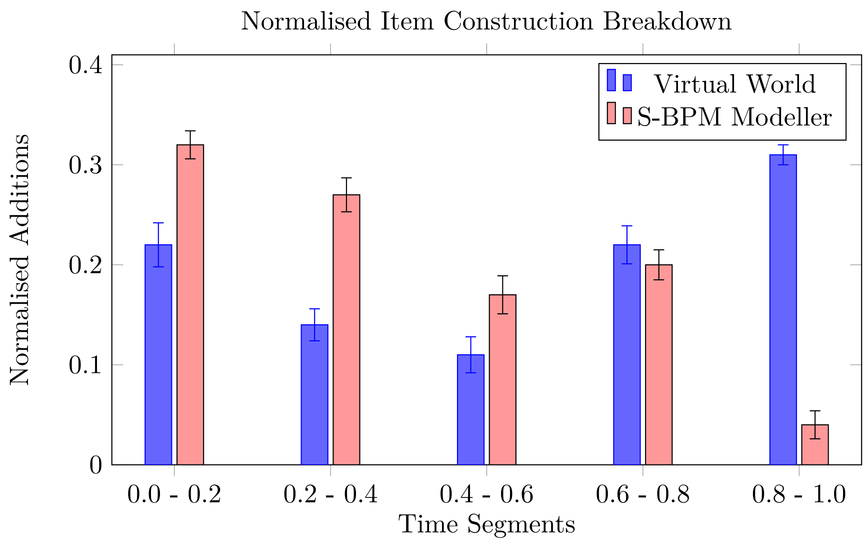

Figure 6: Normalised item creation over time breakdown comparing the virtual world and S-BPM process modelling tool.

The below heatmaps, however, suggest that the participants were instead restricting their movements to the areas required for the necessary actions and explored very little. This conclusion is further supported as the baggage collection area, a place not required for the task, was placed in the bottom left section of the environment and not a single participant entered this area.

Modelling Approach (b): Item Additions and Modifications

The final factor which was considered in this experiment examined the method behind how users arrived at their final process model. This was done in two parts, firstly by looking at how users created their model and secondly, by looking at how they modified the model. This is often referred to as the Process of Process Modelling and is used to identify patterns in the model construction approach [10]. Figure 6 shows an approximation for how items were added over time, by dividing the modelling time into five distinct segments. Note that due to differences in model construction time and the final number of elements between the two groups, both time and number of tasks specified have been normalised.

The below graph suggests that the approach that the model construction approach used by both groups is quite different. Participants in the S-BPM process modelling case appear to specify less tasks over time, while participants in the virtual world experience a trough in completed tasks near the midpoint before specifying the largest number of tasks towards the end of the session. As described in Hypothesis 2(a), participants may also choose to modify the model. To better understand this difference in model alterations, analysis has also been performed examining where these modifications occurred in the modelling process. The results of this analysis are shown in Figure 7 below.

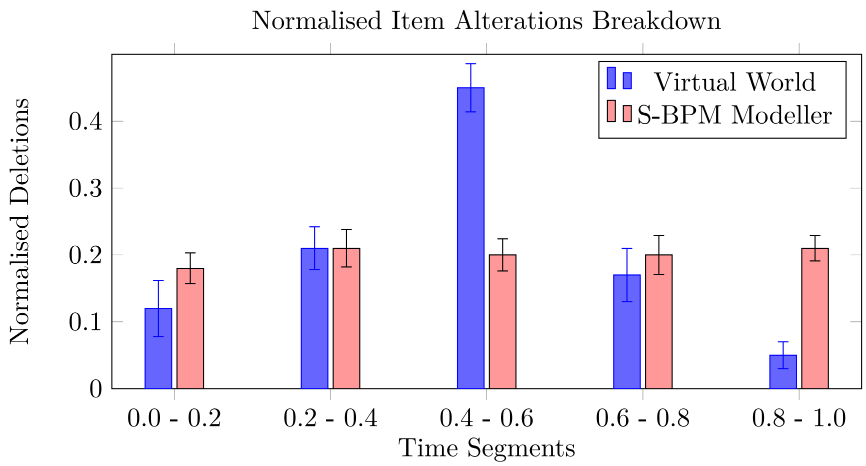

Figure 7: Breakdown of normalised item deletions over time comparing the virtual world and S-BPM process modelling tool.

This graph identifies a major difference in alteration approach between the two groups. The S-BPM process modelling tool has an almost constant rate of deletion throughout the modelling session, while the virtual world group has a distinct rise in alterations towards the midpoint of the modelling session.

7. Discussion

The result of the first hypothesis in this experiment closely matched the expected result. It does appear that the virtual world did prime user memory and enable participants to remember the overall process structure more clearly. This closely matches with theoretical literature which suggests that providing a user with a visual environment encourages them to think about tasks specific to that environment [45]. In particular, the result from Hypothesis 1(c) is quite interesting. Despite participants in the virtual world using more overall words to explain their models, their choice of words was more concise, with participants reusing words approximately twice as often as those using the S-BPM process modeller. This result is consistent with the findings of Qu et. al. (2013) [38], which found that perceptual priming in virtual worlds could prime specific keyword responses. Furthermore, the naming provided by virtual world participants is more suited to the specific task being described (e.g. Boarding Pass) whereas the naming provided by the S-BPM process modeller case may be considered more abstract (e.g. Ticket) and refer to a variety of items. Concrete, concise and consistent naming is of great importance when either analysing a group of models for similarities, or trying to merge multiple views into a single process [7]. If descriptions are not consistent, analysts may not recognise that these varying action descriptions correspond to the same task. To answer the first research question, it does appear that the virtual world elicitation tool, in this experiment, did result in participants constructing better overall models.

The result of the second hypothesis also closely matched the expected result. Participants in the virtual made fewer alterations to their model and the subjective confidence scores given by those in the virtual world were also higher than the scores provided by the users given the S-BPM process modeller. While this confidence may have simply been a result of the better performance by virtual world users, the lack of correlation between the number of tasks recalled and model confidence suggests that this is not the case. As this rating was comprised of a single subjective score, this confidence score is not necessarily exemplary of their overall model confidence, but the total lack of correlation between subjective confidence and overall steps recalled does suggest that the difference in confidence between the two groups may instead be a result of fundamental differences in the modelling approaches.

Further exploratory examination of the modelling approach also revealed significant differences in modelling time. A major concern noted in earlier interviews was that it may become too time consuming for participants to model complex processes using the virtual world [25]. In particular, the time required for users to move about the world and interact with objects was considered to be a risk with this approach, as stakeholders are often unwilling to spend copious amounts of time constructing their models [18]. In this experiment, however, virtual world participants spent a much larger percentage of their modelling time developing their model (54.2%) than the S-BPM process modeller case (41.4%). This difference is largely a result of the S-BPM process modeller group spending a significant amount (32.1%) of their time adjusting the visual arrangement of their model, a task which has no significance on the final model quality. The exact cause of the higher idle time in the S-BPM process modeller cannot be determined with the information available, but we hypothesize that lower idle times were evident in the virtual world as participants were considering future actions while they were traversing the environment whereas the same forethought was not achieved during model rearrangement. Additionally, the heatmaps shown in Figure 5 indicate that the virtual world participants were role-playing in a task-oriented manner and not strongly distracted by the unfamiliar platform for role-play. As the virtual world approach took significantly less time for the participants to work with, this also indicates potential benefits when using this tool with process stakeholders. Requiring less time and training on the part of the stakeholder may improve engagement and overall stakeholder attitude during elicitation, as they are often unable or unwilling to put in the time required for accurate model construction [31].

The analysis of how tasks were created over time revealed that participants which were given the S-BPM process modeller specified fewer tasks over time. This was most likely a result of participants not necessarily specifying tasks in order of execution, but instead in order of recall. Over time, participants found new tasks harder to recall as they had already specified core process steps. This effect was not seen in the virtual world, however, with the largest number of tasks being specified at the end of the modelling session and a slump occurring near the midpoint. This may have been because the virtual world encourages participants to execute tasks in order of completion, not in order of recall. Examining how model modifications occurred over time also highlighted a key difference in editing approach. Users given the S-BPM process modeller had an almost constant level of modifications throughout the task, whereas the virtual world group had a large spike towards the midpoint of the task. The exact cause for such a concentrated grouping will need to be investigated further, but such a large number of modifications, primarily item deletions, in the this one location may suggest that these changes were not made to refine the model but to instead correct mistakes. This may indicate that some virtual world users did not adequately understand how the tool functioned at the start of the test but instead gained this knowledge during the task.

8. Limitations and Threats to Validity

As this was primarily an exploratory study which aimed to generate some preliminary data on the use of virtual worlds in the scope of task elicitation, the results presented come with certain limitations. All virtual worlds are not equal, the level of detail in the environment, user controls and the level of interaction within the world have the potential to greatly affect the observed outcome. To develop rigorous claims about the efficacy of virtual worlds for elicitation, these results need to be replicated within other environments. Furthermore, this work evaluated the two interfaces against a single business process. The results obtained may have varied greatly if participants were exposed to a different process, particularly one which was not as spatial as the airport scenario. There are also limitations in this study with regards to the modelling language chosen. In this work, the S-BPM modelling language was chosen as the comparative case, but the grammar exposed to participants in the S-BPM process modeller treatment may impact on the number of tasks participants are able to specify. As this experiment involved the use of two distinct tools, there was also the potential for usability differences to impact on the results discovered. To try and control for this, a software usability questionnaire [31] consisting of several seven-point Likert scale questions was provided to participants with analysis revealing no significant differences between the overall usability scores in the virtual world (M = 5.65, SE = 0.12) and the S-BPM process modelling tool (M = 5.56, SE = 0.10), $t(62) = 0.62$, $p < 0.53$. This does not mean that no differences in usability were present, but does suggest that the observed differences were more likely caused by the modelling approach to which they were exposed. Finally, as the training videos given to the two user groups also had differences, it is possible that one group was trained better than the other. In an attempt to control for this, participants were asked to rate how well they believed they were trained for the given task, with similar responses being observed in both the virtual world (M = 6.09, SE = 0.18) and S-BPM process modeller (M = 6.25, SE = 0.13), $t(62) = 0.71$, $p = 0.48$.

In addition to these limitations, there are certain threats to the ecological validity of these findings. The participants were generally quite young, with many coming from a technology background and reporting previous virtual world usage. This suggests that while the virtual world cohort in this experiment may have found the tool easy to use, the target audience of expert process stakeholders may not have this same background. Additionally, participant knowledge of the process was normalised by providing them with a summary of the tasks before they began. While this approach has been used previously when looking to prime novice modellers [39], it does result in the outcome potentially being influenced by the participants' ability to recall short-term information, rather than commonly repeated actions. This issue was partially controlled by asking participants to provide additional information not included in the task description, but it nevertheless did prime participants with knowledge they may not otherwise have recalled. Finally, despite the replication of the relationship between modelling behaviour and model quality described in Claes et al. (2012) [10], the direction of this relationship still cannot be determined without designing a repeated measures modelling test.

9. Related Work

Due to the multi-disciplinary nature of this approach, related work in several domains has been considered. Memory priming, virtual world, and modelling language theory has been already been discussed (Sections 1-3) to provide an understanding behind the approach, but similar approaches which aim to facilitate better process elicitation or stakeholder engagement have not yet been considered.

Process elicitation methods usually comprise of workshops, interviews, and process modelling by domain experts (top-down) as well as process discovery based on mining techniques (bottom-up). Several novel top-down approaches have been recently proposed. Some of these methods aim to extend current techniques by providing stakeholders with tangible modelling interfaces to assist in visualisation [20], with further work integrating these interfaces directly into existing modelling tools [34]. In [30], an alternate approach to process elicitation (BPME) based on to-do lists and combining content analysis and process mining is described. In particular, based on the to-do lists, the individual views of the process participants are derived in terms of process models. These individual process models are then to be integrated into the process model that reflects the overall business process. This method is extended to the BPMEVW method by using a complementary virtual world approach [7]. Specifically, the meta data that is necessary to integrate the individual process models can be enriched by the virtual world context, e.g., exploiting information on shared resources. Other virtual world applications in this scope have also been examined, with an aim to improve remote collaborative modelling by allowing modellers to use natural gestures (such as pointing or waving), which would not be possible in a standard tool [37]. The role-playing approach to process elicitation has also been considered previously using storytelling [2]. While this approach does not focus on memory priming, it does attempt to allow stakeholders to describe process information without the need for formal modelling grammar. Instead, users use a series of web forms to simulate both actions and communications in a more natural manner.

Finally, this work was largely informed by work from Claes et al. (2012) [10], which found that both the time required to construct models and the amount of modifications made were negatively correlated with model quality. While this approach does not specifically aim to improve stakeholder elicitation methods, the authors do conjecture that better understanding of process modelling success factors could lead to better stakeholder training and subsequently better quality models. This claim is further strengthened as the results of this study were largely consistent with the findings of Claes et al. (2012) [10], with further work being needed to thoroughly investigate this relationship between modelling behaviour and model quality.

10. Conclusion and Future Work

The results from this study have highlighted several key areas of interest. In particular, they suggest that virtual worlds do provide an effective platform for stakeholder knowledge elicitation. The virtual world may not only allow stakeholders to describe processes in a much more autonomous and natural manner, but results also suggest that virtual world users were able to recall a larger number of process tasks and place tasks in correct order more often than those using a more standard process modelling tool. This result holds much significance as accurate knowledge elicitation and model generation is critical for quality analysis to be performed. Additionally, results also indicate that process stakeholders were are able to fully construct these models much faster in the virtual world than they could using a more standard process modelling approach. This difference appears to be, in part, due to the task-oriented nature of participants in the virtual world, with these users opting to role-play the required tasks instead of exploring the environment.

The results from this study strongly indicate the benefits which could be achieved through better process elicitation. While research examining the suitability of various modelling languages for process description is important, emphasis must also be placed on improving the way in which information is elicited from process stakeholders. In this study, a virtual world was employed to investigate how perceptual priming may affect episodic memory recall, but further work is still needed to determine other ways in which elicitation techniques may also be improved.

As this is the first empirical evaluation which has been performed with regards to virtual world potential in process elicitation, there is a significant amount of work which still needs to be done. While the results from this study indicated that a virtual world tool is effective at priming user memory, further research needs to be conducted to determine the ecological validity of these results. In particular, evaluating the effectiveness of this world when used by expert stakeholders would be the logical next step in the evaluation of this approach.

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