Using Activity Theory as a Framework in a
User Context Analysis

by

Christine O'Connor, BPhysEd(Hon), BA

A thesis submitted to the
Faculty of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of
Masters of Arts

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Christine O'Connor

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Chair

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Abstract

A case study is presented where a User Context Analysis was conducted to determine the relative usefulness of a voice-based system and a hand-held device. A multi-method approach was used that was based on Activity Theory's principles and framework. An informal observation session followed by face-to-face interviews resulted in an *a priori* framework. Observations of assemblers' activities were used to analyze their tasks and to transform the *a priori* framework into two working frameworks. Further observations were conducted to note unplanned disturbances in assemblers' work processes. It was discovered that the current voice system was incompatible with the WMS, however the findings clearly demonstrated the need for a hands-free system. Results show that Activity Theory's framework is efficient because interview and observation data were mapped directly to it. However, the framework was lacking because it does not explicitly include an environment element. A proposed change is to add a 'physical environment' element that encapsulates the framework.

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Using Activity Theory as a Framework in a User Context Analysis

In January 2000, a computer system with a hand-held device was implemented in a large grocery distribution center in Canada. In September of the following year, an interactive voice system (IVS) was introduced in the warehouse meat department as a pilot test. Company managers predicted a 30 percent increase in employee productivity and a sharp reduction of unit repair costs since the system's hands-free capability would reduce the chances of users accidentally dropping their units in everyday use. Management's intention was to slowly replace the existing hand-held device with the new voice-based system. Previous research at the distribution center suggests that neither the hand-held nor the voice-based systems are meeting all the needs of the end users (Madore, 2001). However, that study was carried out on different groups of employees than those investigated here. The goal of this investigation is to determine if either the voice-based or the existing hand-held devices are meeting the needs of a well-defined user group.

A Gap Between a Systems' Usefulness and Users' Needs

The Canadian Oxford Dictionary defines useful as being reasonably effective or successful. In the recent HCI literature, effectiveness is subsumed under the notion of usefulness (e.g., Bisantz, Cohen, Gravelle & Wilson, 1996; Klenner-Moore, 2001). In the context of this thesis, a useful system meets the task demands of the job, functions well, and is usable given the conditions of warehouse environment.

Warehouse distribution tasks have benefited from a wide range of technological advancements. For instance, data entered via barcodes provide real-time feedback for warehouse managers on stock. Even though numerous systems have been implemented to improve productivity, many Human-Computer Interaction (HCI) researchers have reported gaps between these systems and end-user needs (e.g., Bardram, 1997; Klenner-Moore, 2001; Vicente, 1999). Bardram (1997), for example, found that end users did not use a new hospital information system because it only supported a fragment of users' tasks. Bisantz, et al. (1996) give an example of cooks in a quick-service restaurant ignoring a cook decision-making system because it did not fit their work practices. The system's purpose was to provide real-time cooking instructions and to estimate the amount of product on hand. To provide a steady stream of real-time inventory feedback, the cooks needed to use precise amounts of product. However, restaurant activity is cyclical, with workers being busiest during lunch and dinner hours. During peak hours, the cooks were too busy to enter information into the system, and subsequently entered inaccurate data during slow periods. Bisantz et al. concluded that the system designers failed to take into account the workflow of the restaurant's kitchen.

Karlsson (1996) has argued that the primary problem exists between the makers and users of technology. Originally, computer experts filled both roles, but today computers are used at all levels of an organization. Thus, understanding users' needs has become a more complex task because of the wide range of educational and cultural backgrounds, computer experience, and tacit knowledge. There are many approaches to understanding users needs, such as systems' engineering, cognitive and user-centered

design approaches. These approaches tend to address human-computer interaction components (e.g., user tasks or knowledge). Nardi (1996) and Karlsson (1996) argue that addressing the human-computer interaction is not enough because users are complex and unpredictable, and therefore they need to be considered part of a larger system—one that see the human, computer, physical environment, and cultural environment as components all interacting to service a common purpose.

Bridging the Gap

Lindgaard (1994), Thomas (1996), and Beyer and Holtzblatt (1998) claim that an effective system meets users' needs. To determine if a system is meeting users' needs, HCI researchers conduct an analysis of intended users' tools, tasks, and environment, formally known as a User Needs Analysis (UNA). The term 'user needs' can refer to problems that hinder users in achieving their goals, or to learning how users' goals can be accomplished more effectively using a new technology. One objective of a UNA is to understand users' needs to establish the functional specifications of system requirements, which is used to project users' future tasks. UNA deliverables include a stakeholder report, task analyses, user profiles, cost/benefit analysis, a test and evaluation plan, and a user context analysis (Lindgaard, 1994; Maguire, 1997). The purpose of this research is to determine the relative usefulness of the IVS and the hand-held devices, therefore only a user context analysis (UCA) is relevant to this study.

A UCA is the analysis of users, their tasks, their tools, and the physical and social environment in which the tools are being used. This can be accomplished by a UCA because it analyzes a system in terms of its 'quality of use', which according to Macleod

(1994), opens the way to making informed decisions. Of noteworthy importance is the variation in terminology. Maguire (1997) uses the term User Context Analysis, Thomas & Bevan (1996) use the term Usability Context Analysis, while ISO/DIS 9241-11.2 (1997) uses the term Context of Use to refer to the analysis of users, their tasks, their tools, and their physical and social environments. For the sake of simplicity, the term User Context Analysis (UCA) will be adopted here.

It has been repeatedly shown that to fully understand users' needs, the technologies under investigation must be studied as part of a user's ongoing activity (e.g., Karlsson, 1996; Lindgaard, in press). In a user requirements elicitation study, Karlsson (1996) demonstrated that observing ongoing activities revealed requirements that would not have been identified otherwise. In her case study of a passenger information system, for instance, Karlsson discovered factors (e.g., weather) that influenced users to alter their travel plans en route, thus making it necessary to add features that would assist travelers planning a trip as well as travelers in transit. In the company in which the present research was performed, assemblers are observed on the job to identify all the factors, including social, cultural, organizational and environmental, that have been shown to influence the human-computer interaction (Beyer & Holtzblatt, 1998; Noyes & Baber, 1999). Karlsson (1996) refers to this as a 'use activity', Suchman uses the term 'situated actions', while Bevan (2002) refers to this as 'context of use'. These terms essentially mean that actions are a function of the activity, context and culture in which they occur.

Conducting a UCA is particularly important because a system's usefulness can be severely degraded in certain work environments. The work conducted by Madore (2001)

suggests that the warehouse environment may be sub-optimal for voice-activated communications because of competing noise. Similarly, the warehouse meat department may be sub-optimal for hand-held devices because of the cold temperature. The warehouse is a dynamic, fast-paced workplace in which employees perform physically demanding jobs in cold temperature, sometimes under poor lighting conditions, and with loud ambient noise. In addition, many warehouse employees must meet quotas and work standards. A quota is a fixed number of grocery items IVS users are expected to pick during a shift. In contrast, work standards—an optimal workload that most warehouse employees must meet—are calculated by industrial engineers who consider methods, processes, environments, and health and safety issues. In the present company, these standards have been incorporated into the Warehouse Management System (WMS) in an attempt to optimize workflow. The WMS knows how long it takes an assembler to move a long-john (a motorized vehicle) from shelf X to shelf Y in aisle Z. An employee whose work has been standardized is expected to meet standards with a margin of $\pm 5\%$. However, the WMS does not capture the reality of the dynamic work environment. For instance, if an employee is delayed in doing his job because his hand-held unit needs a new battery, it appears to management that this employee was too slow at doing his job because it took him an extra ten minutes. In this situation, the employee informs his supervisor of this delay by handing in a delay sheet at the end of his shift. Warehouse employees are responsible for keeping track of delays (events that delay work tasks) while supervisors are responsible for keying them into the system. If a supervisor forgets to enter the employee's delay time or the employee forgets to report it, the warehouse

employee is reprimanded for ‘stealing company time’, thus creating resentment towards that particular supervisor (Madore, 2001). This reprimand typically occurs days, if not weeks, after the event, at which time the employee has forgotten the event that resulted in the delay.

Purpose of this Research

The purpose of this thesis is to conduct a UCA to determine the relative usefulness of the two technologies and to determine the appropriateness of Activity Theory, a Russian-originated theory to understanding human activity, as a theoretical framework.

Structure of this Thesis

This thesis begins with a discussion of the grocery distribution center, the technologies used, end-users’ tasks, the organizational infrastructure, and environmental context followed by a discussion of approaches to a UCA. User Needs elicitation methods are reviewed in a UCA section. The history of Activity Theory is then reviewed as well as the empirical-theoretical literature, and the procedure for using it as a UCA method. Methods used in this study are introduced, followed by results and discussion. A general discussion is presented and a set of conclusions is drawn.

Grocery Distribution Center

The following sections describe the WMS, the IVS, the hand-held device, the warehouse’s physical and organizational environment, and the grocery order process. The center’s physical environment was of particular concern since it placed considerable

constraints on the methods used in the field study. For instance, most warehouse employees drive vehicles around at high speeds making it potentially dangerous for a researcher to be in the warehouse aisles.

Warehouse Management System (WMS)

The WMS automates the grocery order process by controlling and recording all product and employee movements from receipt of product through order picking and shipment. The WMS controls the entire warehouse operation, including the grocery order process, inventory control, order processing, and delivery. The WMS is integrated with the payroll system, product distribution systems, account payable/receivable system, the hand-held system, and the IVS.

Interactive Voice System

The IVS allows users to communicate with a computer via speech. The IVS provides speech output independent of a user's request and recognizes speech input within the boundaries of its vocabulary. It is wearable allowing assemblers to work hands-free. Each assembler uses a voice recognizer unit with a headset enabling them to send and receive voice instructions from the WMS (Figure 1 below).

Figure 1. The IVS system.

The IVS shown in Figure 1 comprises a headset, a microphone, and a battery operated speech recognizer unit. Not shown is the waist belt that holds the speech recognizer.

The system is designed to adapt to outside noise and is trained to each worker's speaking voice, including articulation, which allows workers to speak in a natural voice. Each user 'trains' the system to recognize their speech by running a program prompting the user to repeat a combination of numbers, letters, and words. A user profile is created, and during usage, the system compares the user's speech to this profile. The system has long and short training programs depending on whether the user is a new user or needs to retrain the system on numbers, letters, and words.

Users log on with a sign-on phrase, which when recognized, initiate a dialog consisting of a voice prompt telling the user what to do next and expecting a confirmatory response.

Log On

System:	<i>Please say your logon phrase</i>
Assembler:	<i>John Doe picking</i>
System:	<i>Please repeat your logon phrase</i>
Assembler:	<i>John Doe picking</i>
System:	<i>Logging on John Doe for picking</i>
Assembler:	<i>Sample noise</i>
System:	<i>Sampling noise, please be quiet</i>
System:	<i>Say department</i>
Assembler:	<i>Meat department</i>
System:	<i>Say vehicle type</i>
Assembler:	<i>Vehicle delta whiskey golf (for V-D-W-G)</i>
System:	<i>Say vehicle ID</i>
Assembler:	<i>Vehicle delta papa one zero one (for D-P-1-0-1)</i>
System:	<i>Start picking</i>
Assembler:	<i>Start confirm</i>

System: *2 pallets, one zero three pieces, one two three point one two cube
(for 103 pieces @ 123.12³)*

Log Off

Assembler: *Switch to special menu*

System: *Special menu*

Assembler: *Log me off*

System: *Out for the day*

Assembler: *Confirm final (or temporary)*

Hand-Held Device

The IVS is being used in parallel with the hand-held device. It is a miniature battery operated computer and scanner that acts as an interface between the WMS and the user. The hand-held device has a keypad and a barcode reader for data input and a small display screen for information output. There are currently two models of hand-held units: a smaller one that displays approximately six lines of text in serif font, and a larger one displaying approximately eight lines of text in slightly larger serif font. The larger unit, shown on the left in Figure 2, also has a handle on the back and is heavier than the smaller unit displayed on the right.

Figure 2. Two models of hand-held devices.

When the company that originally made the units was sold, a discrepancy between old and new unit specifications occurred. For instance, the old documentation claimed that the larger units could be operated in temperatures from 0° to 40° Celsius, whereas the new documentation claims -20° to 50° Celsius. A similar discrepancy has been found for the smaller units. Since the freezer department is kept at -25° Celsius, this discrepancy may pose a problem for users in the freezer.

A user of the hand-held computer turns it on by pressing the on/off key on the device. It then leads the user through the data collection procedure with a series of display messages, prompts, and beeps. The first screen the user sees after logging on is a main menu with three options: A-INBOUND, B-OUTBOUND, and C-INQUIRY. Inbound is for users who are receiving product while Outbound is for workers who are loading product onto delivery trucks. Inquiry is for assemblers who assemble product for customer delivery. Once the user has entered all the required information, he requests an order by pressing F1. The next screen is a list of items the employee must assemble for shipping. The user interface is command driven and responds via screen prompts. Users memorize eight commands, as there is no help file. For example, <F1> is the command to request an order.

The screen displays either six or eight items at a time depending on the unit. The user confirms a picked item by scanning its barcode upon which the system scrolls down to display a new item. The user can manually turn off the device by hitting the on/off key. Units automatically turn off after 3 minutes of inactivity. When the user returns to the unit, it opens at that same point in the transaction.

Differences between the IVS and the Hand-held Units

There are two noteworthy differences between the two devices, namely pick instructions and confirmation process. The IVS gives users one pick item at a time whereas the hand-held unit displays at least six. This difference might have an impact on assemblers' job task, performance and job satisfaction. Regarding the confirmation process, when a hand-held user picks an item off a shelf, he scans the barcode to confirm and moves on to the next item on the list. In contrast, when an IVS user picks an item off a shelf, he confirms the pick by verbalizing the product code, located next to the bar code, and verbally confirms the pick quantity. According to management, this extra step has reduced the number of quantity errors (e.g., an assembler picks three items when the system requested four). It forces IVS users to attend to the quantity because they have to confirm it.

Physical Environment

The distribution center warehouses meat, dry goods, canned foods, frozen goods, and so forth. The center is approximately 5 acres accommodating a warehouse, employee offices, reception area, shipping and receiving station, cafeteria, and employee lounge. Most of the space is taken up by the warehouse, which includes a meat department, frozen food department, produce, and grocery department. These departments are physically separate from one another as each has special needs. For example, the meat department must be kept at -5° Celsius, the grocery department at room temperature and the frozen food department at -25° Celsius.

The departments are made up of aisles with shelves on either side. Goods are either stored on the shelves or on the ground. Barcodes, location codes, and descriptions of goods, which are on the front panel of the shelves, inform employees what should be stored below the label. The bottom-most shelf label identifies goods to be stored on the floor.

Organizational Environment

The distribution center is part of a large corporation comprising several such centers. Of interest in this study are operation managers, supervisors, assemblers, forklift operators, auditors and the union. Their roles are described below in turn.

Operation Managers. Operation managers have little interaction with users of the IVS or hand-held units. Their roles and responsibilities include encouraging coordination between departments, ensuring that shipping, receiving and transportation schedules are met, providing a supportive working environment, empowering supervisors to develop and mentor their employees, and planning, organizing and deploying available labour and equipment resources to meet operational budget and service levels.

Supervisors. Supervisors interact with warehouse employees and operation managers on a daily basis. A supervisor's role is to supervise the workforce of a shift, ensure production and schedules are maintained, review workload and plan the correct sequence for the assembly, provide staff direction and training, establish and maintain high personal involvement in the work process, and interpret/administer the Collective Agreement.

Assemblers. Assemblers are the end-users of the IVS and hand-held devices.

Assemblers, also known as pickers, are typically young, full time employees. Their roles include assembling orders, keeping aisles free of product, discarding plastic wrap from the product, informing supervisors of lunch hour changes or delay problems, getting forklift operators to help out with large-quantity picks (e.g., 12 cases of frozen chicken), and informing supervisors of problems with their devices.

An assembler's primary job task is to assemble orders for customer delivery in any of the four departments. They receive an order through the IVS or hand-held. For hand-held users, an order includes the number of pallets needed, the number of items to pick, the volume of the order, the name of the customer, and the pick list, which is the list of items in the order. Hand-held users receive about seven pick items at a time. For IVS users, an order includes the number of pallets needed, the number of items to pick, the volume of the order, the number of items in the order, and the pick list, which assemblers receive one item at a time.

To pick an order, an assembler drives a long-john up and down warehouse aisles, picks items off storage shelves, and places them on pallets. He often rearranges items on the pallet so they stack better. Once the order is complete, the assembler wraps the whole order in plastic wrap and brings it to the loading dock. The order is now the responsibility of someone else and the assembler is ready for another pick list.

The IVS is used in the meat department while the hand-held system is used in all departments. Assemblers trained on the IVS sometimes use it in the freezer whereas

assemblers not trained on the IVS use the hand-held device when working in the meat department.

Forklift Operators. Forklift operators take product (a) from the delivery bay to its designated storage home (put-a-ways), (b) from storage to its designated assembly home spot (let-downs), or (c) to load/unload delivery trucks. Their role is to drive a forklift, load/unload delivery trucks, stock shelves, help assemblers with large picks, remove and discard plastic wrap, and inform supervisors of lunch hour changes or delay problems.

Auditors. An auditor fulfills a quality control role by inspecting the accuracy of randomly selected outgoing orders, providing feedback to assemblers and supervisors, and entering audit data into the database.

Union. The distribution center is a unionized environment. The union handles employees' grievances and ensures that management and warehouse employees adhere to labour, and health and safety rules. Warehouse employees who are also union representatives are called shop stewards.

Grocery Order Process

Grocery stores place orders with the grocery distribution center via the Customer Order Management System. Orders are sent to the WMS and to the Order System. The Order System sends the order to a PC-based Transport Optimization Tool that determines an optimal distribution plan by factoring in time, distance, customer requirements, and delivery efficiency. Once this has been completed, it sends the information back to the Order System and then to the WMS to organize and print the reports needed for dispatch and loading. The entire operation is shown in Figure 3.

Figure 3. The grocery order process.

Once WMS has this information, store orders are organized as to how and when they are to be assembled to meet dispatch times. The WMS then communicates individual orders to assemblers via the IVS or hand-held device. The WMS generates a store's pick list based on truck capacity and product flow throughout the warehouse, not on factors such as product type, container type, and size of item. When an order has been completed, the WMS creates a bill for the store, which is transferred back to the customer

order management system enabling the store to determine the product they are or are not receiving and the status of their order.

Summary

The WMS receives orders via a grocery order process and generates pick orders that are delivered to assemblers via the IVS and the hand-held devices. Assemblers primarily interact with forklift operators and supervisors. Two differences between the IVS and the hand-held device, namely pick instructions and confirmation process, were noted as they may have an impact on assemblers' job task, performance and job satisfaction.

User Context Analysis

According to the industry literature such as ISO/DIS 9241-11 (1997) and the User-Requirements Framework Handbook (Maguire, 1997), a UCA is the analysis of users, their tasks, their tools, and the physical and social environment in which the tools are being used. A UCA in the context of this thesis research is a way of determining if there is a good fit between the voice and hand-based systems and assemblers' needs. Industry literature, however, only describes the components of a UCA; it does not specify a method, framework, or approach in gathering and analyzing data (e.g., ISO/DIS 9241-11; Maguire, 1997; Thomas & Bevan, 1996). In this section, typical UCA methodologies, namely user-elicited information, and observing users in action, and design approaches aimed at understanding users in context are reviewed and critiqued.

UCA Methodologies

The degree to which a technology fits into an organization and is meeting users' needs cannot be ascertained by simply asking users because they tend to summarize their behaviour, describe it in abstractions, or both (Beyer & Holtzblatt, 1998; Holtzblatt & Jones, 1993). Summaries and abstractions will not provide sufficiently accurate and detailed data for a UCA. Moreover, simply asking users is too subjective as it relies on their perception of their needs. In a study monitoring usage patterns of advanced telephone features, Lindgaard (in press) found that actual feature usage was a better predictor of users' needs than their perception of their own needs.

UCA methods include ones that focus on user-elicited information (e.g., Beyer & Holtzblatt, 1998), while others concentrate on observing users in action (e.g., Bødker, 1991; Engeström, 1993; 1996). However, as cautioned by Landauer (1991), not all methods fit every situation. For instance, recording a person's words while conducting a task is not a suitable approach if the environment is too noisy for the collection of spoken words, as in the grocery distribution environment. The fact that assemblers drive long-johns while conducting their job tasks makes it difficult for a researcher to follow them around. Distracting assemblers while driving could affect their attention to driving and thus be a safety hazard. The warehouse is fast-paced and potentially dangerous, so care must be taken to select a method. In addition, assemblers' performance is based on work standards, so they are not likely to want to stop their task for an extended period to answer questions.

User-Elicited Methods

The term user-elicited refers to data collection methods used to draw out information from the users. Some common user-elicited methods include interviews, questionnaires, and Contextual Inquiry, discussed in turn.

Interviews. There are several types of interview styles: unstructured, semi-structured, and structured. The purpose of a structured interview is to ask the same questions of all respondents so that comparisons can be made (Breakwell, 1995). Semi-structured interviews are conducted with a fairly open framework that allows for focused, conversational, two-way communication (McGraw & Harbison, 1997). Although some questions are designed ahead of time, there is the flexibility to probe for details or discuss relevant issues based on responses. In contrast, an unstructured interview is more spontaneous than a semi-structured interview. Although the interviewer has an idea of what information needs to come out of these interviews, at least some of the questions are not designed in advance or asked in a predetermined order (Breakwell, 1995). Unstructured interviews are often audio-taped for later analysis, however the interviewer can also take notes during the interview (Breakwell, 1995).

Interview questions are open-ended or closed. A closed question is one that can be answered by one word or phrase. For example, “How long have you been working at the grocery distribution center?” or “What is your job title?”. In contrast, an open question is designed to invite a person to talk or to volunteer new information (Breakwell, 1995). For example, “Please describe what a typical workday looks like for you.”.

For this study, a structured interview with a combination of closed and open questions was used to capture a wide range of information. The activity of assembling an order needs to be understood culturally and historically because Madore's study (2001) suggests that neither the hand-held nor the voice-based systems are meeting assemblers' needs. It is thus important to determine how transitioning from a paper-based pick list to a technology-based pick list has affected assemblers' work. To achieve this, open-ended questions can be asked to gain insight into how an assembling task has developed over time.

Questionnaires. Questionnaires are a series of questions typically used for statistical or market studies. They typically employ closed questions like "Do you enjoy working in a unionized environment?", however they can also employ open-ended questions to extract more detail from the respondent (Breakwell, 1995). The mode of delivery typically differentiates a questionnaire from an interview, however an interviewer or researcher can read the questions to a respondent.

In HCI, questionnaires have been used to identify and group users (Lindgaard, 1994) and to elicit user needs (Meittinen & Hasu, in press). For this study, it is important to identify and group users of the hand-held and voice-based systems for recruitment purposes. A mix of novice and expert users are included in this UCA because users' needs change as they become more experienced. It was decided that a closed questionnaire would be suitable to classify users of both technologies as it allows this information to be gathered quickly and succinctly, which is important because this researcher does not want to overstay her welcome.

Contextual Inquiry. Contextual Inquiry is a process of observing and interviewing customers that is based on the work of anthropologists and ethnographers (Beyer & Holtzblatt, 1998; Holtzblatt & Jones, 1993). Beyer and Holtzblatt (1998) formalized this technique to fit into the specific constraints of the software development process. A member of the design team goes to the customer's work to observe and talk to the customer as he or she works. The underlying philosophy of this technique is that it fosters a relationship between users and designers. For instance, forming a partnership with their master/apprenticeship model—where a designer takes the role of the apprentice and the user is the master—fosters a relationship between the designer and client. Contextual Inquiry rests on permission to interrupt and ask questions of the user while she performs the tasks under scrutiny, to engage the user in conversation to get a better understanding of their work. From the Contextual Inquiry data, the design team gets a detailed understanding of users' work and needs in the real work situation. Information gathered is then applied to an elaborate body of models (e.g., Contextual Design's Work Flow Model and Cultural Model) to capture user requirements, discussed later.

Contextual Inquiry is not appropriate for the warehouse environment for several reasons. First, assemblers drive long-johns making it impossible for a researcher to interrupt them while performing a task. Second, to meet work standards (i.e., a specified time allowed per pick list), assemblers work at a fast pace making it unreasonable to interrupt them for an extended period while working. It is for these reasons that Contextual Inquiry was not employed here.

Observing Users in Action

Observation is an integral part of this study because it is based on studying assemblers' ongoing activity. In the context of eliciting users' needs, observations have been shown to be very successful (e.g., Hutchins, 1995) and help in the development of technology (e.g., Hasu & Engeström, 2000) because they provide an indication of what people actually do rather than relying on what they say. They are therefore a valuable supplement to interviews and surveys, which seek respondents' opinion. The similarities and differences between the hand-held and voice-based system are of central concern in this research. Observing users of both technologies will help to identify potential problems, advantages and disadvantages of these delivery approaches.

Observations are appropriate in this fieldwork because this researcher can observe use situations without disrupting work, which is important considering assemblers work performance is based on standards. In addition, understanding how the hand-held and voice systems mediate assemblers' activity can only be done by observing use situations. Ongoing activity was thus observed in this study.

Summary

This section discussed a variety of data gathering methods with the intent to review and select an appropriate method for this thesis research. It was decided that Contextual Inquiry was not an appropriate elicitation method since it is not conducive to the warehouse's environment. Interviews and observations were considered an appropriate way of eliciting assemblers' needs because they capture a wide range of

needs without significantly disrupting assemblers' work. For this study, a questionnaire was considered appropriate only for classifying users.

Theoretical Framework for this UCA

This section reviews a selection of possible candidate approaches. Several 'how to' books have been published from a user-centric design viewpoint demonstrating how HCI practitioners can analyze users, their tasks, their tools, and the physical and social environment using various models and techniques. A literature review of relevant methodologies indicates that each of these has its strengths and weaknesses. Contextual Design and Software for Use are discussed in turn.

Contextual Design

Contextual Design was developed by Beyer and Holtzblatt (1998) to help software designers gather user data in a systematic manner. It uses various models to capture information on users' jobs, tasks, tools, and environment. Relevant to this study are the Work Flow Model, the Artifact Model, the Cultural Model, and the Physical Model, discussed in turn.

The Work Flow Model describes how work is broken up across different users as well as how the work is coordinated to ensure that the job gets done. It captures how work is really done including all the formal and informal interactions thus identifying communication pathways and coordination of workflow. Collected through observation and interviewing, the data for the flow model is organized in a diagram that uses different symbols to denote things like (a) who does the work, (b) the communication between

individuals, and (c) communication breakdowns. This model provides a good basis of identifying problems and patterns of communication and coordination of workflow.

The Artifact Model identifies artifacts customers create, use, or modify when doing work. Artifacts could include spreadsheets, post-its, or 'to do' lists. The structure of the artifact is highlighted and its usage is described with respect to the people who use it. Artifacts may be indicative of the current system not meeting user needs, thus the artifact model helps shed light on people's work practices and it helps them think about their work in a tangible manner.

The Cultural Model shows the culture of the users, their values, and constraints. Influences, such as people, organizations, and groups, in the end-user's work environment are graphically depicted in terms of how they influence each other. The Cultural Model provides a tangible representation of intangible forces that help or hinder work. Lastly, the Physical Model describes the physical environment of the workplace.

Beyer and Holtzblatt's Contextual Design describes the work structure and promotes change because it involves manipulating the underlying work structure rather than the artifact. Although Beyer and Holtzblatt's abstract models capture all the elements important to a UCA, (e.g., Artifact Model helps shed light on how the work is done) the authors do not give concrete tools for generating their models, for applying the outcomes of these models, or how to go about putting these models together.

For this study, the primary drawback of Contextual Design is the lack of an overall framework that would enable the models to work efficiently. For example, the authors outline models to create a broad understanding of users' work. Although they

recommend consolidating data obtained from its models to create a representative work model, it is argued here that combining several specific models does not produce one broad model. Of noteworthy concern is the amount of consolidation needed to gain a high level understanding of the issue under investigation. Beyer and Holtzblatt recommend consolidating data from their models to help researchers understand the roles and lines of communication in the organization under study, the artifacts people use to conduct their jobs, the culture of the organization, and the physical aspect of the workplace. Consolidating models may lead to poor data interpretation and representation because the more a researcher manipulates data the more the likelihood of that data being misrepresented increases. It is for these reasons that Contextual Design was not employed here.

Software for Use

Constantine and Lockwood (1999) developed the “Software for Use” methodology to help HCI professionals in the field streamline the user-centric approach into systematic methods for designing software that will match the needs of its users. There are three stages that relate to a UCA, namely Role Modeling, User Role Maps, and Task Modeling aimed at understanding users, their roles, and their job tasks. Role modeling and Role Maps capture the relationships of proposed users while Task Models capture the relationship between proposed users and their tasks. Software for Use excels at involving stakeholders and identifying potential users by focusing on user roles and user modeling to facilitate user interface design, however the approach does not place

enough emphasis on observing users in context, which is clearly not appropriate for a context of use study.

Like Contextual Design, the primary drawback of Software for Use as a UCA approach is the lack of an overall framework. Constantine and Lockwood aim to capture a broad understanding of users by using a various models to gather information about potential users and their organization except the focus is too narrow because each model is designed to capture different aspects of the relationship. For instance, the Structured Role Model captures the relationship of users to the planned system while the Interaction Profile describes the expected patterns of usage by user role. Using multiple models will not provide a high level analysis of the activity under investigation because each model or technique views only a portion of the activity. In addition, Software for Use expends a lot of energy identifying and profiling users because the intent is to target a new product towards an intended user. It was thus decided that Software for Use is not appropriate for this study.

Summary

A UCA is necessary to better understand how the IVS and the hand-held devices are meeting assemblers' needs in the context of their work. The review of 'How-to' approaches has shown that the various models used in these approaches lack a broad and coherent framework needed to see how the two technologies fit into the organization.

Activity Theory

Activity Theory is a multi-disciplinary theory for studying human activity from a cultural-historical perspective. It originated in the former Soviet Union in the early 1930s. The cultural-historical school of psychology was founded by Vygotsky, and further developed by Leont'ev. Engeström operationalized Activity Theory's concepts (e.g., Engeström, 1993; 1996; 2000b) to include a model of human activity—the basic unit of analysis.

Activity Theory is relevant to this study because it offers a framework for organizing and analyzing research findings, it obliges a researcher to observe use situations, and it supports a hierarchical decomposition of an activity. This section reviews an example of the application of Activity Theory to the analysis of work, an introduction to Activity Theory's concepts, and Engeström's framework.

Activity Theory in HCI

Recent papers have reported benefits of Activity Theory in HCI studies. For instance, Turner and Turner (2001) used an activity-theoretical approach to generate user requirements for an automated workflow system to support the student enrolment process. One major advantage Activity Theory brings to their study is the obligation to culturally-historically understand of the activity under investigation—the well-established set of enrolment procedures. Beyer and Holtzblatt's Contextual Design approach (1998) also places importance on work culture (e.g., Cultural Model), but Activity Theory sees all human activity as a result of certain historical developments under certain conditions (Bedny & Meister, 1997). Understanding how a particular

activity developed sheds light on why some activities are done the way they are. For example, Turner and Turner found that that some rules had been in place for so long (e.g., only academic advisors could approve student enrolment) that users of the system did not understand why they existed. Upon investigating this from a historical perspective, the researchers found that the current enrolment process allowed academic advisors an opportunity to familiarize themselves with the students and to counsel them to make their academic choices. Simply knowing that this academic approval rule exists could be viewed as a constraint (e.g., Cultural Model), however Turner and Turner used the opportunity to identify why such a rule existed thinking that it may help later when making design decisions.

Another major advantage Activity Theory brings to Turner and Turner's study (2001) is its unit of analysis—the enrolment procedure. The enrolment procedure is a system of components that include those who carry out the activity, the tools they use, their motive, the community in which the activity takes place, the rules governing their activity, and how work is distributed among community members. By looking at the enrolment activity as a unit of analysis, the researchers were able to gain a high level understanding of the enrolment procedure and the components that influenced the procedure. Beyer and Holtzblatt's Contextual Design advocates a high level analysis of work, however the techniques used in their approach may have a paradoxical effect on the analysis of work. For example, the Master/Apprentice Model states that a member of the design team take on an apprentice relationship with an experienced worker to gather information about that person's work. Beyer and Holtzblatt (1998) argue that customers

are not used to thinking about how they work, but that they can talk about their work as it unfolds. Therefore, seeing work unfold should reveal work details, tacit knowledge, and what matters to customers (Beyer & Holtzblatt, 1998). However, using a Master/Apprentice Model, there is a risk of the team member becoming too involved in the work process, therefore, high level issues such as goals and motives may not be captured. Beyer and Holtzblatt's Flow Model "offers a bird's-eye view of the organization, showing the people and their responsibilities ... tangible artifacts or intangible coordination" (Beyer & Holtzblatt, 1998, p. 95). However, this flow model takes an organizational view. In contrast, Activity Theory takes human activity as its 'bird's-eye' view (i.e., high level, top down approach). In this way, the organizational view is broken into rules, community and division of labour.

Turner and Turner's (2001) use of Activity Theory's concept of contradictions—incompatibilities, conflicts, or breakdowns—was successful in deriving user requirements. Although the concept of deriving user needs from contradictions is not unique to Activity Theory, Activity Theory offers a way to identify contradictions and relate them to an activity system in order to determine their consequences on the organization as a whole. It is reasonable to assume Beyer and Holtzblatt's Work Flow Model (1998) would have noted that the enrolment procedure could be improved. For example, there were mismatches between the fields on the enrolment form and the student enrolment database. However, it is hard to imagine how their Cultural Model would have captured the importance of retaining the extra step of having academic advisors approve the process. Similarly, Constantine and Lockwood (1999) place a lot of

emphasis on users' roles, but little on context. It is argued here that focusing on reducing steps may produce a system that increases the enrolment procedure's efficiency, but the loss of the academics' interaction may cause problems later. Activity Theory offers an approach to analyzing aspects of work that might otherwise be overlooked or excluded by studying different people's perception of the activities under investigation.

In Turner and Turner's study, understanding an activity from a cultural-historical perspective allows the preservation of an important aspect of enrolling students. Activity Theory encouraged the researchers to understand work from both the users' and the community's perspective. Indeed, Activity Theory's strength lies in the obligation to historically-culturally understand the activity under investigation, including community, rules and division of labour.

An Introduction to Activity Theory

Activity Theory's core concepts and Engeström's framework are expanded upon below. Unit of analysis, contradictions and a priori framework are highlighted as they played an important role in using Activity Theory in this fieldwork.

Artifact Mediated Activity

A basic tenet of Activity Theory is that humans use artifacts such as tools, sign systems, and language to mediate activity. Thus, the hand-held and voice-based systems, knowledge, and pick lists are tools used by assemblers to mediate their activity of assembling an order. Madore (2001) found that the hand-held units gave assemblers many problems. For example, often they had to stop their activity because the units had frozen due to technical problems. In such a situation, an assembler would log out and log

in to 'unfreeze' the unit. Because of the inconsistent reliability of the devices, assemblers were often observed looking at the screen to see if a bar code had been successfully scanned. Such additional activities require conscious actions resulting in constant context-switching from device to order. Thus, the hand-held units were hindering, not mediating, the activity of assembling an order.

Object-Orientedness Activity

Activity Theory assumes that every activity is directed towards an objectified motive, an 'object' (Turner, et al., 1999). An object can essentially be anything as long as it can be manipulated or transformed by the subject(s) involved in the activity. In assembling an order for instance, an assembler's activity is directed towards the order. He transforms it from an empty pallet to a completed order by picking items off a shelf and putting them on the pallet.

The concepts of object and artifact are difficult because there is nothing about them that determines whether it is one or the other. It is the activity at any given moment that determines the meaning of an artifact. For instance, the IVS in the systems development process is an object. Designers use tools, such as programming languages, knowledge, computers and so forth, to develop the system. Once finished, the IVS becomes a tool that an assembler uses to assemble an order. If there are bugs in the program and the assembler begins to troubleshoot, the IVS becomes an object once again because purposeful attention is being directing towards it.

Subject, mediating artifacts, and object can be graphically depicted in Leont'ev's (1981) mediational triangle, Figure 4 below.

Figure 4. Leont'ev's basic mediational triangle (Leont'ev, 1981).

The unit of analysis in Figure 4 is the activity of assembling an order. The arrows represent a two-way relationship between assemblers and the mediating artifacts used to assemble an order. It is a mediational triangle because the artifacts such as long-johns, hand-held devices and so forth facilitate assemblers' assembling activity (Leont'ev, 1981).

Development

Activity Theory requires that human activity be analyzed in the context of development, innovation, and change because it sees all human activity a result of certain historical developments under certain conditions and as a continuously developing process (Leont'ev, 1981). Human activity is constantly changing for reasons such as technological advancements, societal needs, and individual needs. Thirty years ago, for example, a typewriter was used to mediate the activity of writing a thesis. For the present thesis, technology played a very significant role in the activity of writing it. At first glance, one may think the only difference is the tool used for writing a thesis (e.g.,

researching, typing, editing). However, from an activity-theoretical perspective, the activity of writing a thesis with a typewriter and writing a thesis with an internet-connected computer are quite different because current technology has changed the nature of researching, writing, and editing.

Unit of Analysis

The basic unit of Activity Theory's analysis is an activity, a network of actions. In Figure 4, for example, the assembling activity consists of assemblers' actions and operations that are directed towards their order. The unit of analysis encapsulates this activity. According to Leont'ev (1981), the purpose of a unit of analysis is to orient the person (or persons) conducting the activity towards its object. In the distribution center, the unit of analysis under investigation is the activity of assembling an order using either the hand-held or the voice-based systems.

Hierarchical Structure of Activity

Within Activity Theory, there is a three-level hierarchy, making up a unit of analysis, of human activity (Leont'ev, 1981).

Human Activity. Human activity at the highest level of analysis is conceptual, not observable. A need motivates a person into action, which translates the concept of activity into observable reality. For example, if a person has a need for income, but does nothing about it, it remains a need. If this same person begins to look for a job, the actions associated with looking for a job changes the need into a motivated activity. Motives are not always conscious or fully understood by the person having them. For example, if a person has been working for years, the motive for going to work may be

forgotten. Since motives are not observable, researchers need to observe the activity under investigation and then ask the subject(s) of the activity questions relating to motive, needs, and goals.

Actions. Actions, the second level of analysis, are intentional and are therefore conscious acts. A person's actions are goal oriented because they answer the question *what needs to be done*. In the grocery warehouse for example, a possible goal in helping a coworker is to get a new roll of plastic wrap for him. What needs to be done to accomplish this goal is drive a long-john to the office area, get a new roll and return to him with it. Goals can be understood in relation to the object, something a person can transform, and motive of a particular activity.

In practice (e.g., Turner & Turner, 2001), human activity is viewed as collective including all involved in it, while actions are viewed at the level of the individual(s) performing them. In the warehouse for example, the cooperative efforts of warehouse employees may be motivated by the need for an income, thus the activity is the collective activity of operating a warehouse. To operate a warehouse, management has to give different jobs, actions in Activity Theory terminology, to its employees such as assembling orders, replenishing stock, and loading delivery trucks. Engeström refers to this as a network of actions (2000a). The operations associated with the job of assembling an order include driving a long-john, picking items off shelves, and stacking goods onto pallets.

Operations. Operations are the methods used to carry out the action and answer the question *how can it be done given the current conditions*. Operations are triggered by

the material conditions of the environment (Bedny & Meister, 1997; Bødker, 1991). In the distribution center, the technology determines whether assemblers enter commands using voice or fingers. These conditions include both external factors, IVS versus hand-held device, and internal factors, such as knowledge. Operations are made up of discrete tasks, the basic components of activity.

Engeström's Framework

Engeström expanded Leont'ev's triangular framework (see page 30) to include Rules, Community, and Division of Labour to account for the socially distributed nature of human activity (Engeström, 1993; 1996).

Figure 5. The core features of an activity system, as schematized by Engeström (1993; 1996).

The entire figure is defined as a system because the elements (e.g., subject, rules, community, etc.) are interrelated and they interact for the common purpose of transforming the object into an outcome (Shepherd, 2001). Accordingly, such a model is referred to as an activity system. Each arrow in Figure 5 represents two-way interactions between the elements it connects. Subjects, for example, use artifacts but they also interact with other groups (i.e., community) within the activity system. The elements may be defined as follows:

1. Subject. Assemblers are the subjects in the activity of assembling an order.
2. Mediating Artifact. The IVS, hand-held device, the WMS, pallets, and pick lists are mediating artifacts.
3. Object. The order is the object because assemblers' actions are directed towards it.
4. Rules. Rules are explicit, such as standard operating procedures, written protocols, and labour laws, or implicit such as social norms, conventions, and software preference.
5. Community. The community comprises managers, supervisors, auditors, and forklift operators who all play a role in making sure orders are assembled.
6. Division of Labour. Division of labour is the way the workload is distributed and the division of power and status (e.g., management and warehouse employees).
7. Transformation Process. The transformation process is the process of changing an object into an outcome (i.e., turning an empty pallet into a full pallet).
8. Outcome. A full pallet is the outcome of assembling an order.

Elements in Engeström's framework are specific to that action under investigation. Thus, the activity of assembling an order may differ from that of loading a delivery truck or of operating a warehouse.

Leont'ev's Three-Level Hierarchy and Engeström Framework

Leont'ev's three-level hierarchy may be related to Engeström framework as follows. In Engeström's study of redesigning work (2000b), the overall activity of diagnosing a patient was decomposed into four primary actions: [1] reading patient records and test results; [2] examining and diagnosing the patient; [3] calling the lung specialist; and [4] deliberating and making a decision. Each was then developed into four activity systems or, to use Engeström's words, frameworks. The object in [1]—reading patient records and test results—is the patient's records. The purpose is to understand the problem, which is the outcome of this action. The tools used to perform it include medical knowledge and experience. Operations are a subordinate unit of analysis and in [1] include getting and printing the patient's file from the computer. In contrast, the object in [2] is the patient. The purpose is to diagnose the illness and the outcome is to provide a preliminary assessment. The tools used include stethoscope, questions, and medical knowledge. The physician was the subject in [1], [2] and [3], but the lung specialist was the subject in [4]—deliberating and making a decision action.

An activity system can be viewed as the standard lens of an activity—it keeps an entire activity system within its frame (Dayton, 2000). This snapshot shows a high level viewpoint of an entire community that makes up an organization. However, this lens has the ability to focus and can therefore 'zoom in' to the level of one or more actions that

make up the activity system. This snapshot is at the level of individual subtasks and thus gives a clearer picture of the way people actually perform their tasks in the context of their work conditions.

Contradictions

Activity theorists look for contradictions among the elements of one or more activity system to identify opportunities for improvements. A contradiction comprises recurring breakdowns in an activity. Breakdowns manifest themselves in unplanned disturbances in work processes that might force a person to pay attention to an otherwise unnoted detail of the ongoing activity (Hasu & Engeström, 2000). A ‘frozen’ unit, for instance, forces the assembler to pay attention to the unit rather than the task.

Contradictions within an activity system are usually experienced as breakdowns at the level of actions, and according to Activity Theorists (e.g., Engeström, 1999), they can only be understood by studying the entire activity system. The goal of identifying contradictions is to achieve a better understanding of the issues that are initiating or inhibiting change. Engeström argues that to better understand these issues, “it may be very fruitful to move from the analysis of individual actions to the analysis of their broader activity context and back again (1999, p. 32).

Categories of Contradictions. The distribution center has many activity systems that involve many people, artifacts, rules, roles and responsibilities. So, just like a network of assemblers’ actions make up their activity, activities within the distribution center form a network of activity systems. Contradictions are categorized as primary intra-activity, secondary intra-activity, and inter-activity contradictions shown in Figure

6, page 38. This diagram illustrates three categories of contradictions—symbolized with lightening bolts—and was adapted from works by Engeström (1993; 1996) and Turner & Turner (2001). A primary contradiction is a breakdown between actions belonging to a single element within a given activity system. For example, typing incorrect data into the hand-held device is shown in Figure 6 as an artifact problem. A secondary contradiction is a breakdown between elements within a given activity system. For example, assemblers may load all items on a pick list even when the size of the load exceeds safety standards (Madore, 2001), leading to a breakdown between assemblers and rules.

An inter-activity contradiction is situated between two activity systems.

Madore's study (2001) found problems with the pick lists assembled by the WMS because it organizes these by pallet capacity and product placement in the warehouse yet ignores bulk and weight of product. As a result, assemblers had to break their pick list in two because the system would at times tell the assembler to pick chips before bottled spaghetti. Breaking a pick list means that the remaining items are put back into the WMS and given to the next assembler requesting a pick list. In turn, breaking orders increase the total number of pallets on a delivery truck which means the trucks may run out of capacity before all the goods are loaded thus violating the WMS generated orders based on delivery truck capacity. This is shown as a problem with the order in the activity system 'assembling an order' and a problem with the truck capacity in the activity system 'shipping and receiving'.

Figure 6. Three categories of contradictions (Turner & Turner, 2001).

Activity systems refer to various levels of work, for example, an organizational level such as 'running the warehouse', a departmental level such as 'shipping and receiving', or the subject level such as 'assembling an order'. Hasu and Engeström (2000) identified high-level activity systems between two organizations: the organization that built the technology under investigation (Brainview Company), and the organization that used it (BioMag Laboratory). The activity-theoretical perspective allowed the researchers to follow a process that began with a high level analysis of two activity systems to a low level analysis that focused contradictions within and between these systems.

Activity Theory's 3-level activity hierarchy and Engeström's framework is well suited to this research because the intent of the UCA is to determine which technology is better meeting assemblers' needs, not to redesign work or the technologies. It is therefore appropriate to begin the analysis with a top-down approach and delve deeper, if necessary rather than the other way around. In this study, observations of ongoing activities are

sufficient for a high level understanding of warehouse activities. Further observations and interviews will allow warehouse activities to be examined in detail thus enabling this researcher to identify contradictions between one or more activity systems.

A Priori Framework

An *a priori* framework represents the elements of an activity system (Figure 5) early on in an investigation. Hasu and Engeström (2000) coined the term *a priori* framework in a study identifying end-users needs of a medical device, a magneto-encephalograph (MEG). They identified several *a priori* activity systems by researching the MEG itself, and by interviewing the producers as well as the end-users of the MEG. From the *a priori* framework, they hypothesized several potential contradictions between end-users and producers' activity systems and investigated these contradictions by further observing end-users using the MEG in real situations. So, Hasu and Engeström used *a priori* frameworks to formulate early hypotheses and directed subsequent observations towards confirming or disconfirming these hypotheses. This is advantageous because it focuses observation perhaps earlier than would be possible without an *a priori* framework.

The concept of a priori frameworks will be used here because it will help focus the investigation of the IVS and the hand-held system.

Strengths of Activity Theory Approach for this Research

An Activity Theory approach is well suited to this research because it shifts the focus from the user and tool to the activity. Like Contextual Design, Activity Theory proposes that activity cannot be understood without understanding the role of artifacts in

everyday existence. However, Activity Theory goes well beyond understanding the intended users' role and their tasks because it proposes that the activity under investigation must also be historically understood. For instance, knowing how assemblers received their pick order before the hand-held device was introduced may shed light on the current activity and potentially uncover a need that the new technologies are not meeting. Similarly, knowing how the work culture helped shape the activity over time might shed light on assemblers' constraints. The following highlights Activity Theory's strengths that have yet to be addressed.

High Level Analysis of Tasks

Activity Theory provides a high level analysis of assemblers' tasks because it takes activity as the unit of analysis rather than, for example, scanning an item. A task analysis, a UNA deliverable, is a systematic analysis of tasks and behaviours. Traditionally a task analysis is performed early in the design process, although it can be done at any time.

More than 30 task analysis methodologies were surveyed from the literature (e.g., Kirwan & Ainsworth, 1992; Lindgaard, 1994, Schraagen, Chipman & Shalin [Eds.], 2000). The data obtained from the surveyed task analyses are used to: (a) design usable interfaces, (b) redesign an existing system to provide a better match between human and computer, (c) redesign work and tasks to promote automation, and (d) redesign work and tasks to reduce human error (Stammers & Shepherd, 1995). For this thesis, the emphasis is on the context of use rather than a detailed understanding of users' tasks and sub-tasks. It was thus decided that a specific task analysis method was not necessary because like a

task analysis, Activity Theory supports a hierarchical decomposition of goals to be accomplished.

Figure 7 illustrates the hierarchical structure of ‘assembling an order’ using Leont’ev’s model (1981), where the unit of analysis is the activity of assembling an order. The actions associated with assembling an order have been broken down into operations and tasks.

Figure 7. Activity Theory’s 3-level hierarchy of assemblers’ activity.

In Figure 7, the unit of analysis is assembling an order, which includes assemblers’ actions and operations. Focus is given to the second level, actions, because an activity is made up of a network of actions such as requesting a pick order and wrapping an order. Assemblers pick items off a pick list. The operations associated with the action of picking an order include picking up items and placing them on a palette, scanning barcodes and driving a long-john, as shown in Figure 7.

In order to understand the cultural and historical aspects of the activity, assemblers’ actions and use of tools must be observed in the context in which they occur. Changes over time must be noted from one context or community to another (Rohrer-

Murphy, 1999). For this thesis, a historical-cultural understanding was achieved by looking at how assemblers' tools have changed throughout the years and tracing how these changes affected their tasks.

Task analysis methods analyze current tasks without regard for the history or wider socio-cultural contexts. For example, Hierarchical Task Analysis (HTA) and GOMS (goals-operators-methods-selection rules) both decompose goal-oriented tasks into sub-tasks and sub-goals but these tasks are directed towards an ideal state (Card, Moran & Newell, 1983; John, 1999; Shepherd, 2001; Stammers & Shepherd, 1995). In Activity Theory, goals are associated with a person's tasks, which are directed towards a transformation process but not an ideal state. The motive is shared among all who are involved in the high level activity whereas HTA and GOMS focus on an individual. Contrary to HTA and GOMS, which focus on details of the individual's goals and actions, Activity Theory concentrates on broad patterns of activity. For these reasons, Activity Theory was used in this study.

Data Integrity

Researchers who have used Activity Theory have found it extremely useful for organizing descriptive data and classifying problems into categories (e.g., Collins, et al, in press; Kaptelinin, Nardi & Macaulay (1999). Indeed, conducting an analysis of two technologies will yield large amounts of descriptive data and it is therefore important to categorize, organize and maintain the integrity of the data. Activity Theory's principles and Engeström's framework will be used to categorize, analyze and interpret data that

records warehouse employee behaviours, interviews and observations and map these directly to the elements of activity systems.

Activity Theory and UCA

Activity Theory is an approach to understanding assemblers' actions as a mediated, socially determined, multilevel, goal-oriented interaction between humans, their tools, and their environments (Kutti, 1996; 1999). Understanding human activity from this multi-faceted perspective is particularly important because the warehouse is noisy, cold, complex, and fast-paced—factors that might influence IVS and hand-held usage. It is for these above-mentioned reasons that Activity Theory was employed in this study.

Summary

Activity Theory is a theory for studying human activity from a cultural-historical perspective. Engeström operationalized Activity Theory by developing a system of six components that were discussed here. The concept of contradictions was examined as a method of identifying opportunities for improvements in the warehouse.

It was shown that Activity Theory shifts the focus from the user and tool to the activity and argues that activity cannot be understood without understanding the role of artifacts in everyday use. Engeström' framework was discussed as a means to categorize, analyze and interpret data that records warehouse employee behaviours, interviews and observations and map these directly to the elements of activity systems.

Methods, Results, and Discussion

A three-phase approach was employed. In Phase 1, information was obtained through interviews and initial observations to learn more about the history of the distribution center, the IVS and the hand-held device and the culture of the center. Its purpose was to enable the formulation of an *a priori* framework for assembling an order (Figure 8, page 75). Phase 2 involved categorizing users and observing their day-to-day work. The purpose was to generate detailed task descriptions and to verify and refine the *a priori* framework to be used in the third phase. The IVS and hand-held device were evaluated separately. Phase 3 consisted of contextual observations with the purpose of identifying disruptions in day-to-day tasks. To better isolate device specific problems, the task of assembling an order was analyzed separately for the IVS and hand-held devices. All three phases and their activities are shown in Table 1.

Table 1

UNA Methods

	Method	Technique	Subjects	Purpose
P H A S E 1	Initial Observation	Informal observations of ongoing activities	Employees of a large grocery distribution center	<ul style="list-style-type: none"> - Understand relevant context(s) within which activities occur - Start building <i>a priori</i> framework - Identify the elements of the activity systems
	Initial Interview	Semi-structured format	<ul style="list-style-type: none"> - 1 senior manager - 2 supervisors - 4 assemblers - N=7 	<ul style="list-style-type: none"> - Further develop <i>a priori</i> framework - Understand the socio-historical dimension of the activity - Understand the user
P H A S E 2	Task Analysis	Observations of normal work activity	<ul style="list-style-type: none"> - 2 experienced + 1 novice primary user of the IVS - 1 experienced + 1 novice primary user of the hand-held system - N=5 	<ul style="list-style-type: none"> - Analyze the hierarchical structure of the activity - Solidify the activity systems—the transformation of <i>a priori</i> frameworks to working frameworks
P H A S E 3	Contextual Observations	Observations of normal work activity to find disruptions in day-to-day job tasks	<ul style="list-style-type: none"> - 3 experienced + 1 novice user of the IVS - 1 experienced + 2 novice users of the hand-held system - N=7 	<ul style="list-style-type: none"> - Analyze the disruptions - Identify and categorize contradictions

Phase 1 - Initial Observation

Procedure

As the researcher was not familiar with the warehouse environment, the purpose of the informal observation session was to gain a preliminary understanding of the distribution center's community, employees' roles, constraints, and warehouse jargon. This informal session allowed the researcher to observe work without disrupting it. Ongoing activities involving mainly assemblers and forklift drivers were thus observed to learn more about (a) the organization's culture and climate, (b) the tools assemblers used to perform their job, (c) what or who assemblers' actions were directed to, and (d) community/division of labour by observing employees' roles and tasks. The researcher took field notes during this observation. Senior operations management had briefed employees on the study and its purpose prior to conducting the session.

Results

The field notes were analyzed at a high level to yield a picture of the collective activities of employees. Data were sorted into six categories consistent with the elements identified by Engeström (1993; 1996). Duplicates were eliminated, summarized and used to develop an *a priori* framework, shown in Figure 8 below.

Figure 8. *A priori* framework based on initial observations.

Discussion

As shown in Figure 8, the intercom system, the WMS, computers, printers, IVS, hand-held system, and so forth mediated subjects' activities. Employees' common object was the product, which included the timely receipt, delivery and storage of grocery products. Implicit rules such as looking busy, not fraternizing with managers, and explicit labour laws mediated the relationship between employees and community. The warehouse community consisted of management, full-time and part-time employees, and janitors. The workload was distributed amongst assemblers, forklift operators who receive goods, load goods, or replenish stock, janitors, supervisors, and managers.

Due to the size of the warehouse, management often used the intercom system to communicate because it was the easiest way to track down a particular person.

Camaraderie noted between assemblers and forklift operators (warehousemen) did not exist between management and warehousemen. Instances such as loud singing (music was piped into the intercom system) jovial behaviour, and informal chats were observed on several occasions in the grocery and produce departments but not in the freezer and meat departments where people were more work focused. Cooling fans keep these departments colder than the rest, resulting in a noisy environment. Workers in the meat and freezer departments keep moving to stay warm, and the loud fans make it difficult to hear the music and each other.

The next step was to interview individuals to learn more about users and the socio-historical context of their work. Interviews at this stage are appropriate, allowing focused, two-way communication, which helps to develop rapport with the interviewees.

Phase 1 - Initial Interview

Subjects

One senior manager, two supervisors, and four assemblers, all IVS as well as hand-held users, were interviewed individually in sessions taking approximately 20 minutes. The purpose was to gather cultural-historical information about the distribution center to continue developing a priori frameworks.

Materials

The Informed Consent Form (Appendix A) provided detailed information about the purpose of the study, participants' involvement, and the methods used. An interview protocol (Appendix B) provided a consistent introduction to each subject while the

written debriefing (Appendix C) thanked each subject for his participation, and concluded the researcher's involvement with each subject.

A total of 31 interview questions (Appendix D) comprising a mixture of open-ended and closed questions were developed to gather information about the organization, the IVS, and the hand-held device. The questions, based on the information needed to flesh out the *a priori* framework (Figure 9), were divided into four sections: general, IVS/hand-Held, organization culture and climate, and questions for management only. Assemblers were asked the first 22 questions. Managers and supervisors were asked 20 of these as well as an additional nine questions. Eleven questions addressed general issues such as the respondent's job title and function, the length of time they had worked at this workplace, and so on. Another six questions dealt with the IVS and hand-held devices, asking about the perceived quality of training and what interviewees liked and disliked about each device. Five questions concerned the organizational culture, asking questions about job satisfaction and about working in a unionized environment. The remaining nine questions, for management only, addressed issues such as report generation, expected benefits to implementing the IVS, and human error.

Procedure

The management team recruited interview volunteers. Upon obtaining verbal approval, the interviewee read and signed the Informed Consent Form. The researcher then read the initial interview protocol aloud and proceeded with the interview. Responses were recorded using pen and paper.

Results

Raw data are presented in Appendix E. Interview data were added to the *a priori* framework and is shown in bold face in Figure 9 below.

Figure 9. A more developed *a priori* framework based on interview data.

Figure 9 represents a more developed *a priori* framework based on interviews with managers, supervisors and warehousemen, indicated in black italicized font. The grey italicized font represents details found in the previous stage.

Discussion

The subjects and the object remained the same as before, but details were added to the four other categories. Most was learned about the tools employees use and about

the rules of the workplace. Auditor, a valuable detail, was added to the division of labour element. The auditor's job is to inspect the accuracy of randomly selected outgoing orders, verifying that items have been correctly picked, checking a selected pallet, and noting any damage to the product. The auditor's findings are then entered into a database and used by management to monitor employee performance and create reports.

It was learned in the interview that an assembler's performance is based partly on quantity errors (e.g., an assembler picks three items when the system requested four). One assembler believed he made fewer errors using the IVS than using the hand-held, which made him happy because his performance record had improved. Indeed, interview data revealed that the IVS has reduced quantity errors by 15%, probably because it has a confirmation step that the hand-held system does not. However, one drawback is that only a maximum of 12 users can be logged on at any time. Considering the number of assemblers throughout the warehouse, this technology would not seem the most attractive to implement.

Interview data shed some light on the socio-historical dimension of an assembler's activity. Before the IVS and hand-held systems were introduced, assemblers were given a printout of a whole pick list. They would drive up and down the aisles, pick items, cross the item off the list, and move to the next item on the list. Once completed, they would get another list. Assemblers thus saw the whole pick list and had some control over how the order was assembled. Three of the four assemblers interviewed who had used the old system preferred the current technology even though it removed some of their control. This researcher thought the difference between the pick

instructions (i.e., the IVS gives one instruction at a time whereas the hand-held unit displays six instructions) might have an impact on assemblers' job task, performance and job satisfaction, however this was not the case. The benefit of being hands-free clearly outweighed any negatives as only one IVS user mentioned this during the interview or during the course of the field study. Based on feedback from users and management, the new technologies have reduced errors and improved productivity since assemblers no longer need to stop after each pick to cross the item off the pick list. It was thus found that even though assemblers had more control over their assembling tasks than they currently do, they prefer the new technologies because they are more efficient. It is particularly interesting and counter-intuitive that even though assemblers have less control over their tasks than they did in the past, they still prefer the IVS. One would think that less control would be negative, but these findings clearly highlight the fact that an assembler's performance is measured by productivity and errors. These findings support the IVS because it reduces quantity errors, thus demonstrating the need to culturally and historically understand the activity under investigation.

In general, both management and assemblers believed that employees adhered to formal rules and regulations. However, one assembler felt that there were deviations regarding smoke breaks. One supervisor rewarded his employees by "cutting them some slack" by allowing them extra time off during breaks. Most subjects felt well informed about important information. One assembler felt he was not always informed because he worked an atypical shift structure. Assemblers are informed of changes to their work at the beginning of a shift. In one instance, a manager communicated to assemblers at the

beginning of a shift that standards had been changed to reflect the “grab factor”. Small and lightweight items, indicated by a red dot next to the barcode, now had to be picked two at a time. IVS users start the evening shift at 3:00pm, but this person started 1:00pm, and missed the information.

Whereas all the assemblers liked working in a unionized environment because of job security, it frustrated management because they could not reward outstanding performance. All four assemblers were motivated by money, while only one supervisor mentioned money. All management subjects felt their work was recognized by their superiors, but assemblers did not. Management, but not assemblers, received incentives such as reimbursed meals, hockey tickets, bonuses, and wage raises. For instance, one supervisor said he was rewarded for a particular incident by the company paying for a “nice” meal. Whilst this does necessarily imply assembler job dissatisfaction, it implies perhaps a lack of fairness. All assemblers, for example, said their good work was not recognized but their bad work was. In contrast, management felt that their good work was recognized by their superiors. Interestingly, management is not unionized, therefore there are work incentives in place. Taken together, these interview data suggest that the warehouse’ socio-cultural environment is having a disparaging effect on warehousemen’s morale.

Interview data were further analyzed based on positive and negative comments. The IVS received more positive than negative comments mainly because it is hands-free while the hand-held system received no positive comments from assemblers. In contrast, the hand-held received more negative than positive comments mainly because they tend

to break down and are costly to repair. Thus, management and end-users prefer the IVS to the hand-held because it is hands-free.

One assembler said he preferred the hand-held unit because he could see seven pick items at a time. This subject claimed that knowing what was ahead helped in planning his order.

Management preferred the IVS because of the reduced quantity errors and they did not need repair as often as the hand-held units. All IVS users claimed the alphabet-coding scheme was easy to remember because it is based on the military system (e.g., A = Alpha, B = Bravo, C = Charlie). They recalled that it took approximately a week to learn the IVS and memorize the coding scheme, which they felt was relatively quick. All IVS users felt the dialog was easy to remember and somewhat natural.

All warehousemen complained about the female-generated voice used by the system. Interestingly, two users referred to it as “she” and “her” when making negative comments about the IVS. For example, one user said that “10 hours is too long to listen to her”.

Phase 2 - Activity Theory-Based Task Analysis

Subjects

Two expert and one IVS novice user, one expert and one novice user of the hand-held system were observed for a minimum of 45 minutes and a maximum of two hours as they interacted with these devices. Observation periods depended on the length of pick order, temperature of the environment, and availability of the assembler. Expert users

were defined as assemblers who had more than one-year experience on the IVS or hand-held system, while novice users had less than one-year experience.

Materials

The User Profile Questionnaire (Appendix F), based on Lindgaard's user profile questionnaire (1994), was developed to categorize users as expert or novice users of the technologies. Questions about physical disabilities, handedness, and native language were asked in case these impacted the assembler-technology interaction. However, due to the small number of subjects and the lack of data, this researcher was unable to determine if this was the case. The informed consent, verbal protocol, and written debriefing are given in Appendix G, H and C, respectively.

Procedure

Supervisors recruited the participants who were provided with the Informed Consent Form. They were told that the purpose was to obtain information on their job tasks and assess the adequacy of the tools used to support them in their job. Participants were informed that they would be observed while performing their job and that they might drop out of the study at any time without any consequences. Upon obtaining verbal approval, the participant was asked to read and sign the consent form and the researcher filled out the User Profile Questionnaire by asking the participant relevant questions from the questionnaire. For example, questions regarding IVS experience were not relevant to hand-held users.

Observations included all tasks involved in assembling an order. The researcher coded users' tasks (e.g., S&L = stop and listen, G = get) and took notes while observing

assemblers performing their day-to-day job. To ensure that logon procedures were observed, subjects were targeted at the beginning of their shift. The researcher then followed each subject while preparing and completing an order. Each observation session included at least one full order.

Results - Task Analysis

Results were analyzed and tabulated based on Activity Theory as follows: (a) identify actions of the activity, (b) identify the goals associated with each action, and (c) identify the operations needed to accomplish each action. Since the purpose of this phase is to better understand assemblers' tasks and not perform a detailed task analysis, summarized in Tables 2 and 3 below is a high level representation of the actions associated with assembling an order for IVS and hand-held users respectively. A detailed task analysis specifying assemblers' operations—the methods used to carry out an action—can be found in Appendices I and J.

Table 2

Task Analysis for Users of the IVS

Activity = Assembling an order → Motive = paycheck		
	Sequence of Actions	Goal
1.	Check board	• to see where they are working
2.	Get Long-John (LJ)	• to get a good LJ – assemblers get to know what long-johns are faster than others
3.	Get Device	• to get a good IVS – assemblers get to know what units are less problematic than others
4.	Logon to WMS	• to get paid (like punching in)
5.	Logon to IVS	• to get the first order
6.	Assemble	• to meet quota
7.	Wrap	• to keep the load secure
8.	Drop-off	• to finish order and get new order
9.	Log off	• to go on break or leave for the day
10.	Leaving for the day	• to get out of the warehouse

Table 3

Task Analysis for Users of the Hand-Held Device

Activity = Assembling an order → Motive = paycheck		
	Sequence of Actions	Goal
1.	Check board	• to see where they are working
2.	Get Long-John (LJ)	• to get a good LJ – assemblers get to know what long-johns are faster than others
3.	Get Device	• to get a good hand-held – assemblers get to know what units are less problematic than others
4.	Logon to WMS	• to get paid (like punching in)
5.	Logon to hand-held	• to get the first order
6.	Assemble	• to meet standards
7.	Wrap	• to keep the load secure
8.	Drop-off	• to finish order and get new order
9.	Log off	• to go on break or leave for the day
10.	Leaving for the day	• to get out of the warehouse

Tables 2 and 3 show the sequence of actions and the goals that drive these actions.

For instance, an assembler typically starts his shift by checking the work board to see where he is working, and then promptly sets off in search of a good long-john.

Discussion – Task Analysis

At a high level analysis (Tables 2 and 3), IVS and hand-held users' actions and goals are the same. When looking at the sequence of actions, there was very little deviation. One exception was found with hand-held users—the order of actions 2 and 3 varied depending on the availability of long-johns and the length of the line-up at the unit storage window. If, for example, an assembler saw a long line-up, he would get his long-john fist. If there were no long-johns at the docking area, he would get a unit and wait until more longs-johns showed up.

The task analysis revealed that assemblers' goals center on meeting standards and quotas. For example, the reason an assembler wants to find a fast long-john is that he thinks he can assembler an order quicker. Although assemblers are not allowed to work too fast ($\pm 5\%$ of meeting standards), this way of thinking may be reminiscent of a time when assemblers were once able to bank time. In the past, assemblers could work very fast to achieve their quotas/work standards well before their shift was done. This practice is called 'banking time'. If an assembler lifted a heavy box, for example, instead of calling for a forklift operator, he would save time on that order and be that much closer to reaching expected performance measures. However, assemblers can no longer bank time and are now expected to work at a pace that will keep them around 100% of meeting quotas/standards.

Results – Framework

Task analysis data allowed this researcher to develop a working framework, where assemblers are the subjects and the order is the object, based on the *a priori* framework (Figure 9) from the previous method. Figure 10 shows the framework for IVS and hand-held usage.

Figure 10. The activity system of assembling an order where the IVS or hand-held units are assemblers' primary tools.

Figure 10 is no longer an *a priori* framework, but rather a working framework used for subsequent analyses. In contrast, Figures 8 and 9 are considered *a priori*

frameworks because the initial observation session and interviews did not provide enough detail to generate a working framework. Task analysis observations shifted the focus from all warehouse employees to assemblers, as indicated by the subject element changing from '*All employee's*' (Figures 8 and 9) to '*Assemblers*' (Figure 10).

Discussion - Framework

There were very few differences between IVS and hand-held users, therefore only one framework was generated for both. This was anticipated because their motives are the same, their jobs are the same, their actions are the same, and their activities are directed towards their order. The differences between them were observed at the operational level. If the purpose of this thesis was to redesign work or the technologies, it would have been important to generate two frameworks, but this was not the case. Problems, conflicts, and so forth were noted, however these are discussed in terms of contradictions in the next phase.

As predicted, assemblers' tasks are very physical with little opportunity to make decisions. For the most part, assemblers' followed the pick order generated by the WMS. However, one hand-held user was observed picking 'out of order' (i.e., not picking the items in the given order). Recall that hand-held users see approximately seven items at a time, so only hand-held users can do this. This researcher thought that maybe this user picked out of sequence because the pick order did not make sense. When questioned about his reasons, he had none other than "because he was there". The WMS generates the sequence of an order based on product proximity, which includes alternating sides of an aisle, therefore an assembler picks an order by zigzagging through an aisle. In this

instance, this assembler's long-john was too far forward, blocking his next pick, so he picked the item on the other side of the aisle instead. Although managers complained about assemblers picking out of order, this practice was only observed once. Since assemblers' quality of work is based more on quantity errors and on how well the goods are stacked, it is not surprising that this is not a common practice.

Some hand-held users scanned the barcode before picking the item while others picked the item before scanning the barcode. When hand-held users were questioned about this pattern, preference for one method over the other was split. However, users who preferred one method, tended to follow that.

The next step is to gather more information about potential contradictions associated with assembling an order.

Phase 3 - Contextual Observations

Subjects

Three expert and one novice IVS user, and two novice and one expert user of the hand-held system were observed between one and two hours, depending on the length of pick order, temperature of the environment, and availability of the assembler.

Materials

The materials used consisted of pen, pencil, paper, User Profile Questionnaire (Appendix F), Informed Consent Form (Appendix G), and written debriefing (Appendix C).

Procedure

The management team and researcher recruited volunteers. Each subject was given an Informed Consent Form (Appendix G) and told that the purpose of this phase in the study was to observe the IVS and hand-held system in use, and that they may drop out of the study at any time without any consequences. Upon obtaining the participant's consent, the researcher filled out the User Profile Questionnaire (Appendix F) as before.

Observations of subjects included all tasks involved in assembling an order. As before, each subject was observed at the beginning of his shift. Each observation session included at least one complete order. The researcher took notes and asked questions while observing. It was argued earlier that unobtrusive observations were appropriate because it was believed impossible to follow and interrupt assemblers while performing a task. However, because assemblers can no longer bank time, assemblers and forklift operators drive their vehicles around at a much safer speed. This observation was made by warehousemen during the initial interview as well. The elimination of this practice made the environment more conducive to shadowing and occasionally asking questions when problems arose. Thus, the observations were more interactive than originally planned but less so than Beyer and Holtzblatt's Contextual Inquiry (1998).

Data Analysis

Data from all phases were pooled and unique problems were examined to determine if they affected one or more elements in an activity system. Three activity systems were generated to categorize contradictions: the collective activity of operating a warehouse; the IVS device mediating assemblers' activity, and the hand-held device

mediating assemblers' activity. The collective activity of operating a warehouse was not identified a priori but generated on the accumulation of data. This activity system was needed because the practice of breaking orders, discussed below, was common and negatively impacted the shipping and receiving department. The contradiction analysis concerned situations where assemblers' attention shifted away from the order to the IVS or hand-held units. Many problems with the devices were due to the warehouse's physical environment. For example, condensation would build up on the microphones rendering them temporarily useless. As a result, a fourth category, physical environment, was added to explicitly capture the contradictions between the devices and the warehouse environment. To reduce redundancy, contradictions that are relevant to both devices are dealt with in the section titled general contradictions.

Some contradictions were more disruptive than others, therefore contradictions were assigned a severity rating based on frequency and impact on users, production, and other departments. Frequency refers to how many incidents were observed. Impact on users refers to whether the contradiction affected an assembler's ability to meet work standards or quotas. Impact on other departments refers to whether the contradiction affected another department's ability to meet their production schedules. Contradictions that were frequent and impacted others were given a high severity rating. These are presented in Tables 4-8 and Figures 11-15 below.

Results

The results presented below are the accumulation of interview, task analysis and contextual observation notes.

Table 4

Contradictions for Hand-Held Users

Primary Contradiction			Severity
(1)	Tool Element	Assemblers wear heavy gloves but the keypad is small. In one incident, an assembler hit the wrong key resulting in an error. He was not able to recover from this error and had to go to the supervisor to resolve the problem. The keypad is used 10 to 50 times a shift.	Medium
Secondary Contradictions			
(2)	Community and Division of Labour	Hand-held units are stored in an area known as 'aisle 40'. The assignment process begins with a supervisor taking a charged unit out of its charger, turning it on to verify that it works, and assigning the unit to an assembler (via computer log). The unit is then given to the assembler who proceeds with the logon process. Even though units appear functional, they often perform poorly during their operation.	High
(3)	Community and Division of Labour	On one occasion, work stopped for several assemblers when the hand-held system indicated there were no orders. A supervisor, who was informed by an assembler, released work from the WMS.	Low

Figure 11. Contradictions found with the use of hand-held devices.

Table 5
Contradictions for IVS Users

Primary Contradiction			Severity
(4)	Tool element	If announcements are being made over the intercom while users are in the middle of a dialog (either giving confirmation or receiving a command), the dialog often needs repeating.	Low
Secondary Contradictions			
(5)	Community and Division of Labour	There is no formal repair process. IVS users verbally inform a supervisor about problematic units and it is the supervisor's responsibility to get those units fixed. If a supervisor forgets, then the unit goes back into rotation and is given to another assembler.	High
(6)	Subject and Rules	Assemblers using the IVS are expected to meet quotas. All assemblers using the IVS were observed writing down the number of items on their pick lists so that they had an idea of how they are doing with respect to meeting quotas.	Low
(7)	Subject and Tool	Assemblers' train the IVS system to understand them in the warehouse environment, so when users try to logon in the office area, the system has problems with speech recognition because the ambient noise in the office area is different from the warehouse.	Low
(8)	Community and Subject	Assemblers put their assigned IVS system in personal lockers that are equipped with two battery rechargers. Assemblers have access to the keys that open all the IVS storage lockers and sometimes IVS parts (e.g., headsets) are removed or replaced with broken ones.	High

Figure 12. Contradictions found with the use of IVS devices.

Table 6

General Contradictions

Primary Contradiction			Severity
(9)	Tool element	All assemblers complained that the batteries for both units frequently need replacing on both systems.	High
Secondary Contradictions			
(10)	Subject and Rules	Some assemblers break their pick orders when they want to leave for the day or take a break. Breaking a pick list means the assembler, through either speech or keypad, requested the pick list be broken into two lists. The remaining items on the list are put back into the WMS and are given to the next assembler requesting a pick list and assembled on another pallet.	High
(11)	Subject and Rules	Some assemblers did <u>not</u> cut orders even when the orders were obviously violating safety standards (e.g., loads well above assemblers' heads)	High
(12)	Object and Community	Two occasions were observed where assemblers cut orders because of an incongruent pick list. For example, one assembler cut his order because the system wanted him to put 25 heavy boxes of pineapple on top of boxes with oranges that did not have a protective cover on it. The heavy pineapple boxes may have crushed the oranges.	High
(13)	Tool and Object	Often orders need to be cut when there are technological problems. For example, a supervisor had to kill an assembler's session on the WMS because the hand-held unit was locked-up, which resulted in an order being cut.	High
(14)	Subject and Rules	The WMS is programmed to send a replenishment order to forklift operators responsible for 'let-downs' when less than 25 items remain. The WMS organizes work based on customer demand <u>not</u> product availability. It is possible for the WMS to generate a pick list requesting more items than on the shelf. When this happens, assemblers short an order by keying or verbalizing the real quantity. In the meat department for example, if the system asks for 40 boxes of pizzas and there are only 25 boxes, the assembler says " <i>grab 25, confirmed</i> ". The system asks for a count, at which point the assembler says " <i>count 25 confirmed</i> ". The WMS reschedules the remaining boxes of pizza as a different order.	Low
(15)	Community and Division of Labour	Often there are not enough long-johns in the docking bay.	Low
(16)	Subject and Object	Assemblers spend a small percentage of time re-arranging boxes to stack better.	Low

Figure 13. Contradictions relevant to both devices.

Table 7

Contradictions Due to Warehouse Environment

Contradiction		Severity
(17)	A verbal dialog or scan needs repeating because assemblers are too far away from the antennas. Antennas may not work as well as specs claim due to high amount of metals in the building and fans, which are factors that reduce radio frequency.	High
(18)	Often IVS users have to repeat their dialog because of the loud cooling system in the freezer and meat department.	High
(19)	The warehouse is not a well-lit environment and hand-held users do not like using the backlight feature because it consumes too much battery time.	High
(20)	Hand-held units freeze when users briefly leave the freezer department to drop off a load. The change in departmental temperature causes condensation in the units that causes the units to freeze.	High
(21)	Frost builds up on the microphones resulting in increased voice recognition errors.	High

Figure 14. Contradictions due to the warehouse's physical environment.

Table 8

Inter-Activity Contradictions

Contradiction Between Assembling an Order and Operating a Warehouse		Severity
(22)	The Warehouse Management System calculates orders based on demand and truck storage capacity. The numbers of pallets, among other variables, make up capacity. If assemblers are cutting orders, the result is more pallets to be loaded onto the delivery truck. This has a negative impact on the shipping/receiving department, which is responsible for getting the trucks loaded and out on time. For example, Madore (2001) found that loaders often had to violate safety standards to get all the pallets onto the trucks.	High

Figure 15. A contradiction between two activity systems: the activity of assembling an order (left triangle), and the collective activity of operating a warehouse, right triangle.

Overall, of the 22 contradictions identified, 14 were high, 1 medium, and 7 low severities based on frequency and impact on users, production, and other departments.

The tool element was associated with seven of the 14 high severity contradiction whereas no pattern was associated with the remaining seven.

Discussion

This discussion considers the 14 high severity contradictions by examining the contradictions attributed to the warehouse's physical environment, technological problems, frequent battery changes, the practice of 'cutting' orders, and the impact the warehouse' community has on assembling an order. Also discussed is how these findings relate to the work conducted by Madore (2001).

The Physical Environment

As shown in Table 7, all contradictions attributed to the warehouse's physical environment were rated high. As noted earlier, the usefulness of a system could be severely degraded in a less than optimal work environment. This statement is clearly supported by field results. Fifteen incidences, totaling five contradictions were attributed to the warehouse's physical environment, signifying that it degraded the usefulness of both technologies under investigation. The freezer environment, for instance, is too cold for the IVS and the hand-held device.

The problem with the freezer's environment is particularly evident when users leave it temporarily. Because of the change in temperature, condensation builds up and causes the systems to freeze. In one incident, a user's hand-held unit froze up in the middle of a pick order. The supervisor rebooted him on the WMS and the assembler resumed picking. This incident was resolved in approximately three minutes. Regarding the IVS, condensation tends to build up on the microphones when assemblers who work in the freezer drive their load to a warmer area of the warehouse and then return to the freezer. In one incident, a user's IVS froze up in the middle of a pick. He went to find

his supervisor and waited about ten minutes in the office for him. The supervisor could not reboot him from the WMS and had to break the assembler's pick order, log him off the WMS, log him back on the WMS, so that he could log back on to the IVS. At that point, the assembler went back to work, but had to wrap the order he was working on and drop it off at a loading bay.

It is presently unknown how the condensation problem could best be resolved, but there are several possibilities. First, the obvious solution would be to purchase equipment designed to work in extremely cold environment for extended periods. For example, the current headsets are not meant to be used in such conditions, however the IVS manufacturer has a headset model that is more robust and is apparently designed for harsh environments. Similarly, the hand-held units were not designed to work in -25°C . These units were built based on USA food storage regulations, which is about 10°C warmer than what the meat department is. Second, the current units could be modified to withstand changes in temperatures. For example, at the time of the study, some units were sealed with silicone, however it was not yet apparent if this sealant reduced the amount of condensation.

Four incidents were observed where users of the systems had trouble communicating with their systems and which were resolved when they got closer to antennas. In one instance, an IVS user received a <cannot talk to server> dialog indicating a communication problem. This communication problem resolved itself once the user moved closer to an antenna. In the meat and freezer department, antennas are located at the end of alternating aisles, illustrated in Figure 16 below.

Figure 16. The meat department has six antennas at the end of alternative aisles.

As the above diagram illustrates, users near the end of the aisles are closer to the antennas than they are in the middle of the aisles. In another incident, a hand-held user's unit froze up in the middle of a pick. He tried troubleshooting by pressing <alt-0> to reset the device but the key command did not work. He then moved down the aisle, closer to an antenna, pressed <alt-0> again, was able to reset the device, and resumed picking. The problem resolved itself once he moved closer to an antenna. In the examples provided, the users experienced problems in the middle of an aisle. According to assemblers, these problems happen because there are not enough antennas. When supervisors were questioned about it, they were not willing to comment. It is possible

that the antennas may not work as well as specs claim due to high amount of metals and fans in the building. An obvious solution to this problem would be to add more antennas.

Technological Problems

On five occasions, an order needed to be cut because of technological problems. For instance, one supervisor had to ‘kill’ an assembler’s session on the WMS because the hand-held unit was locked-up, which resulted in an order being cut via the WMS. The supervisor gave the assembler a new unit. This incident began at 5:10, was temporarily resolved at 5:25, but the new unit was not letting the assembler logon, so the supervisor gave him yet another unit. The user was able to logon at 5:30. It is unclear what causes these technological problems, but it is reasonable to assume that they may be a communication problem. The present data are insufficient to determine how the problem could best be resolved, but adding more antennas may be one way to resolve this problem.

Frequent Battery Changes

During the interview, all assemblers complained that the batteries for both systems frequently needed replacing. However, some batteries perform better than others. In one instance, an assembler was having trouble with his hand-held unit and exchanged it for another one but kept his original battery because he knew from experience that it was a “good one” since all batteries are numbered and labeled. In Table 7, replacing batteries is categorized as a tool contradiction. However, the meat and freezer departments may be particularly hard on batteries because cold temperatures consume more energy than room temperatures. Similarly, hand-held users do not often

use the backlight feature because it consumes too much energy. This is problematic because assemblers have to stop what they are doing to get a new battery, which can take as long as ten minutes. Two factors affect the length of time it takes to replace a battery: where the assembler is in relation to the battery storage area (the warehouse is approximately 5 acres), and whether a supervisor is there to give the assembler a new battery.

When analyzing the three contradictions regarding problematic units, lack of accountability seems to be the central theme. There is no formal repair process for the IVS units. When an IVS user has problems with a unit, he informs a supervisor and it is the supervisor's responsibility to get it fixed. If a supervisor forgets, then the unit goes back into rotation and given to another assembler. Although a formal repair process exists for hand-held units, there is still a problem with assemblers being given poor-functioning units. When a hand-held user has problems with a unit, he informs a supervisor who logs the complaint and puts the unit in a bin. Once full, this bin is delivered to the technology department for repairs. However, interview results and observations revealed that hand-held users are often given "finicky" devices, despite the repair process. An example from observation notes clearly illustrates an assembler's level of frustration with his hand-held unit.

Observation Notes: Contextual Observation #4, novice hand-held user.

The assembler picked up his unit at 2:54pm, logged on with no problems, received his pick list from the hand-held, and started picking his order. Within minutes it was obvious he was having problems with the unit. He was showing physical and verbal signs of frustrations. He commented "piece of junk". At 3:05pm, he cut his bill to get a new unit, wrapped the order, and brought it to the loading bay. He went to the manager's office to get a new unit and began picking a new order at 3:20pm.

Implementing a repair process where all employees are accountable for their part in the process would be one solution to this problem. Reducing the likelihood of units being dropped would decrease the need for repairs. The small hand-held units can be carried in a hip belt, but there are not enough belts to go around. As a result, users have to either carry their units or place them on the items. However, users tend to drop them onto their boxes resulting in damaged devices. Expecting users to carefully place the units down is unrealistic. For example, one user picked 45 items in 30 minutes, which means that he had to put his unit down and pick it up at least 45 times. Ensuring there are enough hip belts to go around would reduce mishaps.

The Practice of Cutting Orders

Eleven incidents, totaling four high-severity contradictions, were attributed to the practice of cutting (or breaking) an order. Results suggest three leading reasons assemblers' cut order, namely incongruent pick lists, unsafe loads, and personal reasons, discussed in turn.

Incongruent Pick Lists. Two occasions were observed where assemblers cut their order because of incongruent pick lists. For example, one assembler cut his order

because the system wanted him to put 25 heavy boxes of pineapple on top of boxes with oranges that did not have a protective cover. The heavy pineapple boxes would have crushed the oranges. In this situation, ‘community’ was identified as the problematic element because managers, supervisors, and industrial engineers have input on how the WMS generates pick orders. The WMS generates a pick list so that assemblers move through the isles without having to turn back—it does not take into account weight, size, or type when determining pick order. This is particularly problematic because if an assembler stops to rearrange his load, he risks not meeting standards, but if he ignores it, product will be damaged and he may be reprimanded for it. However, if he cuts the order, then the remaining items will be loaded on another pallet. Cutting the order simply passes the problem on because it does not affect an assembler’s ability to meet standards, yet it severely impacts the shipping and receiving department.

Although the present data are insufficient to determine how the problem of incongruent pick lists could best be resolved, there are several possibilities. First, there may be a problem with how the WMS calculates the pick order’s volume and pallet capacity. The WMS should arrange the pick list based on type, container, and size of item. Second, it would seem worthwhile to evaluate the information an assembler needs to assemble an optimal load. Currently an assembler knows the number of pallets needed, the number of items to pick, and the volume of the order before picking. Once the picking task begins, hand-held users receive about seven pick items at a time while IVS users receive one item at a time. It appears that this is insufficient for assemblers to

plan their assembling tasks effectively. These two reasons should be examined to determine how orders could be better assembled.

Unsafe Loads. Two occasions were observed where assemblers cut their order because their loads were too high. Results suggest that whether or not an assembler cuts an order varies as a function of his history with management, lack of safety knowledge, training, and experience. For example, one warehouseman felt that if employees cut their orders because they were unsafe, then they would be labeled “difficult”. However, not cutting orders and thus delivering unsafe loads or loads too tall to fit into the trucks is clearly not a solution because loaders must unload/reload the pallet, and rewrap the product so that it fits onto the truck. This backs up the shipping/receiving department.

Although the present data are insufficient to determine how the problem of unsafe loads could best be resolved, there are several possibilities. First, work standards should be evaluated because assemblers seem to be under such time pressure that they sometimes choose to pass unsafe loads on to the loaders. Second, there may be a problem with how the WMS calculates a pick order’s volume and pallet capacity. The WMS should arrange the pick list based on type, container, and size of item. Third, assemblers are not optimizing pallet capacity. These three reasons should be examined to determine why orders are violating safety standards.

Personal Reasons. One incident was observed where an assembler cut his order because it was break time and another similar incident was observed where an assembler cut his order because it was time to go home. Several ways to change assemblers’ behaviour would be for management to reward warehousemen as a team and rotate

employees through the various jobs in the warehouse so they gain an appreciation for other job functions.

The practice of cutting an order highlighted an interesting contradiction at the subject and community element regarding health and safety standards. All subjects interviewed claimed that health and safety standards were important to them. However, the opposite was observed on many occasions. For instance, an assembler was observed lifting several boxes that weighed over 100 pounds. According to him, he should have requested that a fork-lift operator lift the items onto his pallet, but did not because that would take longer than doing it himself. Work standards have not been identified for IVS users, therefore they must meet pick quotas. Standards are more precise because they consider methods, environments, and safety issues. If standards were implemented, requesting a fork-lift for such a heavy load would have been built into picking this particular item. During the course of the study, management did not encourage using safer measures. Assemblers drove around with loads stacked well above their heads. Since the WMS generates pick orders based on pallet volume, management believes an unsafe load is due to an assembler's inexperience of efficiently stacking a pallet while assemblers believe this inconsistency is because management wants to pile as much as possible to get more pallets onto the trucks. It is important to note that unsafe loads were observed in the grocery and produce departments where items vary in size, weight, and vulnerability to being damaged.

One warehouseman, who was not part of this study, felt that if employees break orders because they were unsafe, then they would be labeled 'difficult'. To prove that

managers disregarded safety standards, this particular employee took photographs of various orders that violated safety standards. In fact, this employee carried the photographs around with him while working and was anxious to show them to this researcher in the hope of gaining sympathy for his working conditions. One way to change assemblers' behaviour would be for management to encourage and reward safe work practices and to reward warehousemen as a team.

Communities

The communities in which assemblers interact warrant examination since five contradictions (4 high-severity and 1 low-severity) involved the community element. In general, the problems concerning the community involved a lack of a communication process. The following excerpt is based on observation notes that illustrate the communication problem.

Observation Notes: Subject not part of study.

Assemblers are assigned a personal IVS unit, which are stored in individual lockers. When an assembler has a problem with a unit, he tells the shift supervisor so that the unit can get fixed. In one case, the assembler had been on vacation for a week. He opened up his locker and attached the battery to his unit only to find out it was not working. When questioned about his non-functional unit, he said that the unit was broken before he left and gave it to the supervisor to get it fixed. According to him, the unit being in his locker indicated that it was fixed and is now ready for use. However, the unit was still broken (contradiction between the community and division of labour). In this particular incident, the user spent approximately 3 minutes looking for a unit.

Another similar incident happened when this researcher was waiting in the supervisor's office when an assembler came in to get his IVS from his locker. He took his unit out of his locker, took a battery out of the locker, put the unit in the belt, and put his headset on only to find that it was broken. He remarked that somebody had probably

replaced his good headset with a broken one (a contradiction between community and artifact). Since headsets tend to freeze up when used in the freezer, assemblers often need to replace their headsets with other headsets. The manufacturer has a microphone that is designed to work in colder environment; perhaps investing in these headsets would alleviate this problem.

Assemblers have access to locker keys because supervisors leave them in the top drawer of a desk in their shared office. It is difficult to identify the root cause of these problems. For example, problems such as these may originate from assemblers having access to locker keys or to the lack of supervision or lack of care. On the other hand, the root cause may be because performance is based on meeting standards, so assemblers may not have time to inform somebody about faulty equipment, or because there is no formal repair process. Based on this researcher's experience at the warehouse, it is reasonable to assert that it is a combination of these factors. For example, in the meat and frozen food department, the supervisor's office is a hub of activity. IVS units are stored there so assemblers are either coming in to get their units from the lockers, replacing batteries, getting new headsets, or putting their units back. Extra hand-held batteries are also stored in the office because the meat and freezer departments are quite far from away 'aisle 40' where the hand-held units and batteries are generally stored. Since supervisors spend most of their time in that office, warehousemen were always coming and going into the office for various reasons. Assemblers also tend to be very task oriented, as they are always 'on the clock'. Based on these factors, it is easy to see

why a formal repair process is needed and that warehousemen should be rewarded as a team.

Madore's Study

The sum of the results support earlier work (Madore, 2001) where it was believed that poor employee morale was attributable to two distinct work cultures—that of management and that of warehouse employees. The social dynamics of the warehousemen and management is having a negative impact on employee morale. The complex social dynamics of warehouse employees also affected the mode of data collection used by this researcher. For example, originally, it was intended to videotape the observations. However, because the videocamera visibly upset many warehouse employees, it was abandoned after the first attempt. Upon investigation as to why a videocamera was having such a negative affect on assemblers, it was discovered that industrial engineers had recently finished a study where assemblers using the IVS were observed and videotaped so that work standards could be implemented. At the time of this fieldwork, IVS users were required to meet quotas. According to assemblers, meeting quotas is easier than meeting work standards. Although participation in this thesis research was voluntary, the industrial engineers' work standards study was not. As a result, assemblers were very distrustful of anyone in the warehouse who was not a 'warehouseman'.

The issue surrounding work standards was consistent with some observations made by Madore (2001) while contradictory with others. Regarding consistent findings, management was in favour of work standards because it allowed all assemblers to be

measured by the same standard. In contrast, assemblers were not in favour of them because they felt violated because their tasks were constantly being monitored and judged and management was not. This is another difference in the two cultures. Assemblers feel alienated because they have no control and management is not aware of it, suggesting a lack of communication between the two work groups. The feeling of 'being on the clock' does not foster a workplace morale that is based on empowering teams to do their best for the warehouse as a whole.

Regarding contradictory findings, it appears that with the delay-sheet process, assemblers' did not have any difficulty meeting work standards. Moreover, assemblers were observed working at a comfortable pace and were able to interrupt their tasks briefly to answer questions or to provide clarification. Management, however, approved assemblers' delays and it was observed on several occasions that assemblers had many delays because of troublesome units. When assemblers were questioned about the delay sheet, they tended to brush it off as a minor nuisance. Management claimed that there was no delay-sheet acceptance process per se, but rather they entered the delays into the WMS based on their perception of the assembler (e.g., slacker vs. hard worker) and the reasons given for the delays. When assemblers were again questioned about the delay sheet process, no comments were made regarding management not approving their delays. The insight to be gleaned from the lack of assemblers' feedback is that managers typically accept the assemblers' delay requests.

General Discussion

This section begins with a discussion of the technologies used in the warehouse, then shifts focus by reflecting on the most important insights enabled by Activity Theory's framework, particularly from exploring the rules, community, and division of labour in the workplace investigated. Also discussed in this section is Activity Theory's utility in this research and its limitations based on the results.

IVS, Hand-held Device, and WMS

The observed activities as well as the contradictions noted lead to the findings that neither the IVS nor the hand-held system is ideal for the freezer department. The main problem is that condensation causes both technologies break down, and when they do, they are not mediating the assembling activity. In addition, the WMS was also found to occasionally obstruct, rather than mediate, assemblers' tasks. The main problem with the way the WMS generated pick orders was that its algorithm was deficient as it did not take into account bulk of the item and its susceptibility to damage. As previously noted, this deficiency is also negatively impacting the efficiency level of the shipping and receiving department. Indeed, this research demonstrated that it does not make sense to analyze assemblers' actions without taking into account the overall activities of the warehouse. Nor does it make sense to analyze the technologies outside their context of use. This is consistent with the notion that to design useful systems, actions need to be analyzed as part of a larger system.

Rules, Community, and Division of Labour

The most complex finding was the practice of cutting orders. Activity Theory directs attention to the underlying reasons for observations made in the workplace. An unsafe load, that is, one that is likely to topple or one in which heavier items are placed below lighter ones, is the predominant reason for cutting orders. Unstable loads cannot be loaded into a delivery truck because they may topple over during transport. A task analysis would have stopped at 'loads seem to be unsafe' whereas Activity Theory encouraged the researcher to identify problems via contradictions, step back and relate them to the entire organization. By tracking this problem to the next person in the procedure, it was discovered that this practice is severely impacting the work of the loaders in the shipping/receiving department. As a result, loaders unload and reload the pallets so that they are more stable and better fit into the trucks. This additional activity was found to hold back the loaders, which resulted in a chaotic docking area with full pallets cluttering up the entire area and beyond. In turn, assemblers bringing further loads to the dock were forced to dump these wherever they could fit. While the loaders' computer printout showed where loads should be located, this information was no longer accurate due to the backlog. In a study examining safety and worker performance in the shipping/receiving area of the same company being investigated here, Madore (2002) found that about two-thirds of loaders' time was wasted on locating missing loads and on unloading and reloading goods to make them fit into the truck. This finding could not have been arrived at without considering additional activity systems and other workers' activities. This suggests that a holistic analysis as advocated by the Activity Theory

framework is essential for identifying root causes of at least some major problems within an organization.

The practice of cutting orders highlights the importance of perception, which played a big role in assemblers' actions. For example, it was found that the resistance to, or indifference towards, cutting an order varied as a function of an employee's history with management. The assembler who photographed unsafe loads, for example, is more likely to ignore the fact that a load is unsafe because he believes that assemblers who break orders are labeled "difficult" by management. The new assembler who cut his order because of an incongruent pick list is less likely to ignore the fact that a load is unsafe because he does not know about the tendency of management to label people and is therefore likely to follow rules and regulations without question. To help explain these observations, Activity Theory directs our attention to assemblers' community, division of labour, and rules. Regarding assemblers as a community, they may be indifferent to safety regulations because supervisors' tend to ignore them so they do not invest a lot of time and energy observing or learning safety rules and regulations. Concerning rules, assemblers believe they are likely to be punished for being delayed while assembling orders, so they will just ignore safety rules. Regarding division of labour, supervisors, like assemblers, have to deliver to the same production demands so they are likely to ignore unsafe loads in order to meet their own performance criteria. For example, supervisors are focused on meeting production schedules and do not facilitate behaviours that will impact them while assemblers are focused on meeting standards. Since loaders do not work to time standards, the supervisors do not smooth the progress of a loaders

job. Taken together, these findings reveal that the warehouse's subcultures are conflicting with each other.

Perhaps the most conflicting contradiction was the incongruency between management's claims regarding the importance of health and safety and their behaviour in this respect. On no occasion was a manager observed encouraging assemblers to observe safety regulations, even when they noted unsafe behaviour. Superficially, one might attribute this to a problem with the way the WMS calculates orders. Its algorithm could be improved by taking into account the bulk of the item and its susceptibility to damage. Activity Theory suggests several other possibilities. For example, it could be claimed that the WMS and production schedules are impeding supervisors' supervisory role. Rather than providing assemblers with direction, training, and maintaining a high personal involvement in the work process, supervisors spend the majority of their day monitoring the WMS. For instance, customers must order their goods before 4:00pm for next-day delivery, but some stores submit their grocery orders later than this. To satisfy customers, managers often assign supervisors the task of adding late orders directly into the WMS, thus circumventing the grocery order process. As a result, supervisors spend much of their time ensuring these orders are queued, assembled, and delivered. Similarly, customer orders often get reprioritized in the WMS as a function of an unscheduled need. If a grocery store is having a sale on strawberries, for example, the volume originally ordered may be increased mid-stream. Changes to customer orders are labour intensive, and because there are many of these exceptions, supervisors spend little time on the warehouse floor. It is reasonable to believe that a supervisor's inability to

spend sufficient time ensuring safety standards are kept may be one reason for this discrepancy between perceptions and observed practice. It is also possible that supervisors deliberately turn a blind eye because they, like assemblers, are rewarded for their ability to meet production schedules for their departments. A task analysis alone would not have brought attention to this possibility.

Historical Understanding

The most counterintuitive finding was that even though IVS users have less control over their tasks, they still prefer the IVS to the hand-held unit because it reduces quantity errors, for example, where an assembler picks three items when the system requested four. It is reasonable to assume that Constantine and Lockwood's Software for Use (1999) and Beyer and Holtzblatt's Contextual Design (1998) would have identified this preference, however they would have stopped there. Considering the historical perspective showed that an assembler's performance has always been measured by productivity and errors, and that assemblers are likely to be reprimanded for committing such errors. These findings highlight the need to re-examine the way assemblers are rewarded and the measures upon which management relies for calculating rewards. Seemingly this finding goes beyond the scope of this thesis. However knowing the importance assemblers' place on quantity errors is an important insight that can be used in future decisions such as ensuring future voice systems have a confirmation step. This finding could not have been arrived at without going beyond the IVS and the hand-held device.

Activity Theory's Utility and Limitations

Conducting an analysis of two technologies yielded large amounts of descriptive data and it was therefore important to categorize, organize and maintain the integrity of the data. Beyer and Holtzblatt's four models, namely Work Flow Model, Artifact Model, Cultural Model, and Physical Model (1998), represent different perspectives, different concepts, and different symbols. It is unclear though how a researcher could maintain the integrity of data when applying the same qualitative data to different models. In this research, the same framework and concepts are applied to different activity systems that represented different levels of granularity and different perspectives such as assembling an order and operating a warehouse. This facilitated a systematic categorization and representation of breakdowns in assemblers' activity.

Although Engeström's framework was extremely useful for organizing data and classifying problems into categories, it did not accommodate data pertaining to the physical environment. Yet, the physical environment was the root cause for many system breakdowns. It was therefore proposed to add a 'physical environment' element to Engeström's model that encapsulates the entire framework.

Figure 17. An extension of Engeström's framework.

The above figure was presented in the discussion of results where contradictions between the devices and the warehouse elements were captured and diagrammed by applying the contradictions to the extended framework. Indeed, identifying these contradictions was particularly helpful in determining computer system fit because it shifted the focus from the computer systems to the impact of the warehouse environment on the technologies. Subjects made many statements of the way the environment was perceived to affect their performance.

In one respect, this researcher found Engeström's framework easy to use. For example, data from interviews and observations were mapped directly to the elements of the 'assembling' activity system. However, fitting problems into Engeström's framework

was at times an ambiguous task. It was not always clear where problems fit into the framework because some problems fit into more than one element. For instance, the problem with the IVS not recognizing assemblers' login dialog in the office area was identified as a contradiction between subject and artifact because assemblers could have a better understanding of IVS recognition technology. It could be argued that this is a device problem and we should not force users to adapt to the technology but rather design technology to better meet users' needs. Yet, errorless speech recognition has thus far remained unattainable. Looking at this problem pragmatically, it is easier to inform assemblers that they should log into the IVS while in the warehouse rather than the office area simply because the current technology cannot create more than one profile. Thus one weakness in Engeström's model, which is also a strength of Activity Theory per se, is that a researcher can adopt many perspectives and get a different picture every time. However this is true for any design approach. The issue here becomes one of design trade-offs, which is very context dependent. For example, it is dependent on the users (e.g., novice vs. expert), the work environment (e.g., hazard awareness), and the nature of the tasks (Wickens, 2000). In the case of the grocery warehouse, design trade-offs should be decided at the researcher and management level. This way, users' and management's needs will be incorporated into the trade-off process.

Conclusion

The purpose of this thesis was to conduct a UCA to determine the relative usefulness of the two technologies and to determine the appropriateness of Activity Theory as a theoretical framework. Despite advantages and disadvantages of both the IVS and hand-held technologies, rendering both less than ideal in this environment, the IVS was deemed best because it is hands-free. The IVS was most preferred because it reduced quantity errors. Activity Theory proved very worthwhile as a framework as it drew attention to multiple factors that went well beyond one would expect to identify in conventional UCA methods.

The most important theoretical contribution of this work is the extension of Engeström's framework to include the 'physical environment' element. Practical contributions uncovered several weaknesses unrelated or indirectly related to the technologies. Identifying a gap between perception and reality resulted in novel solutions to the problems found in the organization.

Future Research

Activity Theory, more specifically, Engeström's framework was used to determine if there was a good fit between the voice and hand-based systems and assemblers' needs. Industry literature on UCA is lacking because it does not specify a method, framework, or approach in gathering and analyzing data. Further fieldwork using Activity Theory could strengthen the need to incorporate a theoretical framework into a UCA.

This field study presented a strong case for extending Engeström's framework. Further fieldwork would potentially strengthen the need to incorporate environment into the model.

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Appendix A

Informed Consent (Initial Interview)

The purpose of an informed consent is to ensure that you understand the purpose of the study and the nature of your involvement. This informed consent must give enough information for you to decide whether or not you want to participate in the study. Please ask Christine O'Connor, principal researcher, to clarify any questions you may have. Should you require any additional information regarding this study, please contact Christine O'Connor, 722-1669, coconnor@chat.carleton.ca, or Dr. Gitte Lindgaard, thesis supervisor, 520-2600 x 2255, Gitte_Lindgaard@carleton.ca.

Should you have any ethical or other concerns about this study then please contact Dr. M. Gick (Chair, Carleton University Research Ethics Committee for Psychological Research, 520-2600, ext. 2664) or Dr. K. Matheson (Chair, Dept. of Psychology, 520-2600, ext. 2648).

Project: The Evaluation of the Interactive Voice System (IVS) and Hand-Held Device

Research Purpose: The purpose of this research is to evaluate the usefulness of the IVS. To do so, both the IVS and the hand-held device will be examined.

Research Aim: The aim of this research is to explore the extent to which Activity Theory can be used as a theoretical framework in the identification of user needs. According to Activity Theory, all activity has a motive and all actions have goals. To use Activity Theory, questions will be asked regarding job enjoyment, goals and so forth. These questions will help the principle researcher apply Activity Theory's concepts to a practical situation. The theory also proposes that the culture of a society affects activity, which means questions will be asked regarding types of work groups, work incentives, and so forth.

Research Personnel: This research is part of a Master of Arts Thesis in Psychology at Carleton University in Ottawa, Ontario, Canada. Christine O'Connor is the principal investigator, and Dr. Gitte Lindgaard is the faculty thesis supervisor.

Management Approval: Permission has been granted by the management team at the grocery distribution center for employees to participate in this study.

Task Requirements: Interview – the purpose of the interview is to gather information about the company's culture (i.e., rules, peers, etc.) and information about the IVS and the hand-held device. Data from IVS and hand-held questions will be used to evaluate the extent to which the devices are meeting user needs. Data from culture and motive questions will be used to explore Activity Theory's usefulness in a real-work situation.

Duration and locale: Interviews will take place at grocery distribution center and will take approximately 30 minutes.

Potential risk/discomfort: There are no potential physical or psychological risks.

Confidentiality: All notes will be used for research purposes only. Dr. Gitte Lindgaard, may see these notes for the purposes of inter-rater reliability – determining if 2 people have the same interpretation. No one else will have access to this information. Information collected will be reported in a general way.

Right to withdraw: Participants have the right to withdraw from the study any time without any consequences. Note: Should you decide you do not wish your data to be included, please contact Christine O'Connor to have this information removed at any time (722-1669, coconnor@chat.carleton.ca).

I am aware that the reason for informed consent is to make sure that I understand why the study is being done and how I will be involved.

I have been told that I will be interviewed in this study. I have been informed that the interview will cover the following areas: organization's culture, job tasks, satisfaction with the hand-held and interactive voice system, and work experience. I understand that the researcher needs information about the culture of this environment to understand the terminology and jargon frequently used and to understand how the hand-held device and IVS evolved into what it is today. I understand that I do not have to answer any question that makes me feel uncomfortable and that I may drop out of the study at any time without any consequences in the way I am treated by my co-workers, supervisors and management.

I understand that under no circumstances will any of this information be used to misrepresent or harm me. I further understand that all names will be removed from data and these data will be pooled to represent all users. As a result, no one will be identifiable or mentioned by name. I understand this information will be used to evaluate the extent to which the IVS is meeting my needs as a user.

My signature below indicates that I have read the above information and that I agree to take part in this study.

Signature (subject): _____

Signature (researcher): _____

Date: _____

Appendix B

Initial Interview Protocol

Hi, my name is Christine O'Connor. I am a graduate student studying the interaction between humans and computers.

The purpose of this interview is to gather information about the company's culture (i.e., rules, customs and norms) and information about the interactive voice system and hand-held device. I need information about the culture of this environment for a number of reasons. First, I need to understand the terminology and jargon frequently used. Second, the theory I am using to study human activity obliges me to understand the organization from a cultural perspective. Finally, in order to evaluate the effectiveness of the interactive voice system, I need to know how that tool evolved into what it is today.

All notes and questionnaire responses will be used for research purposes only. Only Dr. Gitte Lindgaard, my thesis supervisor, and myself may see these notes. Information from this interview will be reported in a general way.

You do not have to answer any question that makes you feel uncomfortable and you may terminate this interview at any time without any consequences in the way you are treated by your co-workers, supervisors and management.

Do you have any questions before we begin?

Appendix C

Debriefing

On behalf of Dr. Gitte Lindgaard and myself, I would like to thank you for participating in this study. Your participation will help us evaluate the effectiveness of the interactive voice system and contribute to a relatively new theory in the field of human-computer interaction.

Your time and co-operation are greatly appreciated. If you would like a copy of a research summary or my complete thesis, please contact Christine O'Connor, 722-1669, coconnor@chat.carleton.ca. If you have any questions or comments about this research, contact Christine O'Connor, principal researcher, or Dr. G. Lindgaard, thesis supervisor, 520-2600, ext. 2255.

Should you have any ethical or other concerns about this study then please contact Dr. M. Gick (Chair, Carleton University Research Ethics Committee for Psychological Research, 520-2600, ext. 2664) or Dr. K. Matheson (Chair, Dept. of Psychology, 520-2600, ext. 2648).

Appendix D

Initial interview**General Questions**

1. What is your job title?
2. What is your job function?
3. How long have you been working at the grocery distribution centre?
4. What skills do you think a person needs to do your job?
5. Please describe your typical workday.
6. How did orders get assembled before the hand-held system?
7. Who do you interact with daily on your job?
8. What motivates you to come to work every day?
9. Do supervisors (managers) recognize when you've done a 'job well done'? If so, how do they reward your good work?
10. Do supervisors (managers) recognize when you've not done a good job? Made an error for example or was particularly slow at doing something. If so, how do they react when something has gone wrong?
11. How is job performance measured? Performance reviews for example.

IVS/Hand-Held Questions

12. What do you like about the interactive voice system?
13. What do you like about the hand-held system?
14. What do you dislike about the interactive voice system?
15. What do you dislike about the hand-held system?
16. Did you receive enough training with the interactive voice system?

17. How long did it take you to learn to use the interactive voice system?

Organization's Culture & Climate Questions

18. Do you enjoy your job?
19. How do you feel about working in a unionized environment?
20. Are formal rules and regulations important here?
21. Are Health and Safety rules and regulations important to you or the people you work with?
22. Do you feel you are well informed of important information? If not, please explain.

Questions for management only

23. Do you use reports generated by WMS to perform your job? If yes, what are the different types of reports? What are these reports used for?
24. What tools (e.g., computers, SOPs) do you use to perform your day-to-day job?
25. What benefits were expected by implementing the interactive voice system in the meat department?
26. Did expected benefits actually take place by implementing the interactive voice system in the meat department?
27. What are the basic limitations of the current technology?
28. What are some of the errors people make in the interactive voice system?
29. What kinds of errors are associated with the use of the hand-held device?
30. How is human error detected?
31. What are the steps taken to resolve human error?

Appendix E

Results from Interview Questions

This table shows the results for the questions regarding job tasks, performance, and motivation. The responses were consolidated and multiple responses are indicated with a multiplication symbol beside the response.

Table 9

Initial Interview Questions – General Questions

	Question	Responses - Management	Responses - Warehousemen
1	Job title?	--	--
2	What is your job function?	<ul style="list-style-type: none"> - Senior supervisor (x2) - Operations manager 	Warehouseman (x4)
3	How long have you been working at the grocery distribution center?	<ul style="list-style-type: none"> - 3 yrs - 4 yrs - 1 year 	<ul style="list-style-type: none"> - 3 yrs - 18 yrs - 4 yrs - 4 yrs
4	What skills do you think a person needs to do your job?	<ul style="list-style-type: none"> - Patience, motivational skills, negotiation skills, multi-tasking abilities, management skills, computer skills (x2), analytical skills, people skills, communication skills, organizational skills 	<ul style="list-style-type: none"> - Reading - Speaking English - Physical endurance - Counting
5	Please describe your typical workday.	<p>Supervisor</p> <ul style="list-style-type: none"> - Shift exchange - Check email - Set up shift - Tour building - Interact/interface with supervisor and employees - Baby-sit the WMS <p>Manager</p> <ul style="list-style-type: none"> - Walk through the warehouse to determine what went on during the evening shift - Establish how the day will progress depending on the previous shift's events 	<ul style="list-style-type: none"> - Look at board - Go to work - Work shift - Go home

		<ul style="list-style-type: none"> - Read emails - Look and scheduling and volumes - Adjust manpower depending on volumes - Planning for next business event (i.e., holidays, upcoming specials, etc.) - Putting out fires - Data collection 	
6	How did orders get assembled before the hand-held system?	DALLAS (instead of WMS) An assembler was given a printout of a pick order from the DALLAS system and he crossed each item of the list until it was complete. The assembler would then get another list from the supervisor. Work performance was based on piece-count (or quotas).	
7	Who do you interact with daily on your job?	<ul style="list-style-type: none"> - Operation managers - Supervisors - Employees 	<ul style="list-style-type: none"> - Supervisors - Other assemblers - Fellow employees
8	What motivates you to come to work every day?	<ul style="list-style-type: none"> - Responsibility (x2) - Feeling of accomplishment - Money - Curiosity - Challenge 	<ul style="list-style-type: none"> - Money (x4)
9	Do supervisors (managers) recognize when you've done a job well done? If so, how do they reward your good work?	<ul style="list-style-type: none"> - Yes (x4) - Reimbursements for meals - Bonuses - Hockey tickets - Raises 	<ul style="list-style-type: none"> - No (x4)
10	Do supervisors (managers) recognize when you've not done a good job? If so, how do they react when something has gone wrong?	<ul style="list-style-type: none"> - Yes (x4) - Look for an explanation to implement a process so that it does not happen again - Most problems are "problems with the system not person", so there usually is a possible resolution 	<ul style="list-style-type: none"> - Yes (x4) - Hassled - Warnings - Write-ups - Suspension
11	How is job performance measured?	<ul style="list-style-type: none"> - Performance reviews 	<ul style="list-style-type: none"> - Piece count in meat and freezer (quotas) - Standards in other warehouse departments

This table shows the results for the questions regarding usage of the IVS and the hand-held device. The responses were consolidated and multiple responses are indicated with a multiplication symbol beside the response.

Table 10

Initial Interview Questions – IVS/Hand-Held Questions

	Question	Responses - Management	Responses - Warehousemen
12	What do you <u>like</u> about the IVS?	<ul style="list-style-type: none"> - Hands-free (x3) - Improved work quality (x2) - Reduction in damaged units - Increase production 	<ul style="list-style-type: none"> - Hands-free (x4) - Less mistakes - Improved work quality
13	What do you <u>like</u> about the hand-held system?	<ul style="list-style-type: none"> - Nothing - See next 5 pick locations (plan load a little better) 	<ul style="list-style-type: none"> - Nothing
14	What do you <u>dislike</u> about the IVS?	<ul style="list-style-type: none"> - No technical support - Growing pains - Problems with communication between the IVS and WMS - No work standards (yet) 	<ul style="list-style-type: none"> - Problems with the system not hearing commands - Voice gets annoying (x3) - Not comfortable wearing headset all day - Wires connecting the headset to the voice unit gets in the way
15	What do you <u>dislike</u> about the hand-held system?	<ul style="list-style-type: none"> - Cost of repair units - Units frequently break (x3) - Not hands-free 	<ul style="list-style-type: none"> - Frequently breaks down - Frequent battery changes - Not hands free (x4) - Don't like wearing belt - Manual data entry
16	Did you receive enough training on the IVS?	--	<ul style="list-style-type: none"> - Yes (x3) - No
17	How long did it take you to learn to use the IVS?	--	<ul style="list-style-type: none"> - 1-2 weeks (x3) - 2 shifts

This table shows the results for the questions regarding the warehouse's culture and climate. The responses were consolidated and multiple responses are indicated with a multiplication symbol beside the response.

Table 11

Initial Interview Questions – Organizations' Culture & Climate Questions

	Question	Responses - Management	Responses - Warehousemen
18	Do you enjoy your job?	- Yes (x3)	- Yes (x4) - Especially when receiving
19	How do you feel about working in a unionized environment?	- Frustrating from management's point of view b/c can't pay/reward employees based on performance (x3)	- OK (x4) - Union fees are expensive - Likes job security (x2) - Likes the job security, but does not like that "nothing goes on merit – all based on seniority"
20	Are formal rules and regulations important here?	- Yes (x3)	- Yes (x3) - "It's almost too strict" - No - "Not really, there is too much favoritism, smokers get more breaks"
21	Are Health&Safety rules and regulations important to you or the people you work with?	- Yes (x3)	- Yes (x4) - "It is to me but management doesn't seem to care"
22	Do you feel you are well informed of important information? If no, please explain.	- Yes (x3) - "Sometimes there are oversights"	- Yes (x3) - No - "I have to ask...probably b/c my shift cycle is different than others"

The questions presented in this table were only asked of management as they relate to business issues such as expected benefits in implementing the IVS, and error detection.

Table 12

Initial Interview Questions – Management Questions

	Question	Responses - Management
23	Do you use reports generated by the WMS to perform your job?	<ul style="list-style-type: none"> - Yes - Activity history report - WS report – summary of hrs worked in all areas - Employee performance - Productivity reports
24	What tools do you use to perform your day-to-day job?	<ul style="list-style-type: none"> - Computers, Phone, e-mail, intercom, union agreement manual, IVS user guide, laptop
25	What benefits were expected by implementing the IVS in the meat department?	<ul style="list-style-type: none"> - Increased accuracy - Decreased damaged units - Increased productivity
26	Did expected benefits actually take place by implementing the IVS in the meat department?	<ul style="list-style-type: none"> - Yes to all the above responses
27	What are the basic limitations of the current technology?	<ul style="list-style-type: none"> - IVS – only 10-14 users can be logged on at one time - IVS – only 10 users can be logged on at one time - IVS has problems communicating with the WMS, therefore cannot implement the technology throughout the whole warehouse
28	What are some of the error people make using the IVS?	<ul style="list-style-type: none"> - Quantity errors because they pick ahead – IVS assemblers confirm a pick before they have actually picked the item to speed things up
29	What kinds of errors are associated with the use of the hand-held device?	<ul style="list-style-type: none"> - Quantity errors (e.g., the system asks for 14 and the assembler picks 13)
30	How is human error detected?	<ul style="list-style-type: none"> - Auditors - Supervisor's spot check - Customer
31	What are the steps taken to resolve human error?	<ul style="list-style-type: none"> - Brings it to assemblers attention - Interview employees first, then discipline - Auditors' report - Track errors based on auditors' report - Retraining - Remove the practice of 'banking time'.
		<p><u>Note:</u> Warehousemen cannot bank time anymore, which has decreased the number of quantity errors, increased Health&Safety compliance, and employees now pace themselves rather than work like crazy to meet their standards early in the shift and then take the rest of the shift off.</p>

Appendix F

User Profile Questionnaire

Name: _____

Job Title: _____

User Experience with the hand-held device

- ☐ Less than 6 months
☐ 6 months – 2 years
☐ More than 2 years

User Experience with the interactive voice system

- ☐ Less than 6 months
☐ 6 months – 2 years

Hours per day using the hand-held device

- ☐ Less than 2 hours a day
☐ 2 hours – 6 hours a day
☐ More than 6 hours a day

Hours per day using the interactive voice system

- ☐ Less than 2 hours a day
☐ 2 hours – 6 hours a day
☐ More than 6 hours a day

Work Experience at this warehouse

- ☐ Less than 6 months
☐ 6 months – 2 years
☐ 2 years and more

Personal Characteristics

- ☐ Right handed
☐ Left handed
☐ Ambidextrous

Native Language

- ☐ English
☐ French
☐ Other _____

Disabilities

- ☐ Speech impaired
☐ Hearing impaired
☐ Visually impaired

Appendix G

Informed Consent (Observations & Task Analysis)

The purpose of an informed consent is to ensure that you understand the purpose of the study and the nature of your involvement. This informed consent must give enough information for you to decide whether or not you want to participate in the study. Please ask Christine O'Connor, principal researcher, to clarify any questions you may have. Should you require any additional information regarding this study, please contact Christine O'Connor, 722-1669, coconnor@chat.carleton.ca, or Dr. Gitte Lindgaard, thesis supervisor, 520-2600 x 2255, Gitte_Lindgaard@carleton.ca.

Should you have any ethical or other concerns about this study then please contact Dr. M. Gick (Chair, Carleton University Research Ethics Committee for Psychological Research, 520-2600, ext. 2664) or Dr. K. Matheson (Chair, Dept. of Psychology, 520-2600, ext. 2648).

Project: The Evaluation of the Interactive Voice System (IVS) and Hand-Held Device

Research Purpose: The purpose of this research is to evaluate the usefulness of the IVS. To do so, both the IVS and the hand-held device will be examined. Observing both systems in use and interviewing users will help determine if the IVS is meeting user needs. From these observations and interviews, suggestions will be made on how to improve the IVS from the user's perspective.

Research Personnel: This research is part of a Master of Arts Thesis in Psychology at Carleton University in Ottawa, Ontario, Canada. Christine O'Connor is the principal investigator, and Dr. Gitte Lindgaard is the faculty thesis supervisor.

Management Approval: Permission has been granted by the management team at the grocery distribution center for employees to participate in this study.

Task Requirements: 1. A questionnaire will be distributed to classify users of the IVS and the hand-held into categories. Assemblers who have used either the IVS or hand-held for over a year have been identified as expert primary users, whereas assemblers with less than six months experience with either device are categorized as novice primary users. Employees who occasionally use the IVS are considered secondary users.

2. Two sets of observations will be carried out. Subjects are not obliged to participate in both sets of observations. The aim of the first set of observations is to understand the interaction between users, job tasks and tools. The aim of the second is to understand how well the hand-held device/IVS meet the user's needs. It is important to note that the systems are under investigation, not the users. Christine O'Connor will observe participants performing their day-to-day job, with particular attention given to the usage of the hand-held device and IVS. Christine will be following each participant around while taking notes. She may interrupt and ask questions when necessary and convenient for the participant, and all attempts will be made to make the session as unobtrusive as possible.

3. As soon as conveniently possible (i.e., the day of the observation), an interview session may be needed for clarification and interpretation. Questions relating to the hand-held device, IVS, and job tasks will be asked during the interview.

Duration and locale: Observations and interviews will take place at the grocery distribution center. Observations of tasks will last no longer than 4 hours. Each post-observation interview will take approximately 20 minutes.

Potential risk/discomfort: There are no potential physical or psychological risks.

Confidentiality: All notes will be used for research purposes only. Dr. Gitte Lindgaard, may see these notes for the purposes of inter-rater reliability – determining if 2 people have the same interpretation. No one else will have access to this information. Information collected will be reported in a general way.

Right to withdraw: Participants have the right to withdraw from the study any time without any consequences. Note: Should you decide you do not wish your data to be included, please contact Christine O'Connor to have this information removed at any time (722-1669, coconnor@chat.carleton.ca).

I am aware that the reason for informed consent is to make sure that I understand why the study is being done and how I will be involved.

I have been told that I will be observed and interviewed in this study. I have been informed that the interview will cover the following areas: organization's culture, job tasks, satisfaction with the hand-held and interactive voice system, and work experience. I understand there will be a short questionnaire to identify my experience as a user, native language, job title, and my work experience. I understand that I do not have to answer any question that makes me feel uncomfortable and that I may drop out of the study at any time without any consequences in the way I am treated by my co-workers, supervisors and management.

I understand that under no circumstances will any of this information be used to misrepresent or harm me. I further understand that all names will be removed from data and these data will be pooled to represent all users. As a result, no one will be identifiable or mentioned by name. I understand this information will be used to evaluate the extent to which the IVS is meeting my needs as a user.

My signature below indicates that I have read the above information and that I agree to take part in this study.

Signature (subject): _____

Signature (researcher): _____

Date: _____

Appendix H

Observation and Task Analysis Protocol

Hi, my name is Christine O'Connor. I am a graduate student studying the interaction between humans and computers. The purpose of my research is to evaluate the usefulness of the interactive voice system. To do so I must understand what users need. Since a vital part of understanding user needs stems from understanding job tasks, the purpose of this observation session is to understand your work and all the tasks associated with getting your job done.

During the observation session, I will be observing you performing your work, while taking notes. Try to work at the same speed and with the same attention to detail that you normally do. I will try my best to be as unobtrusive as possible.

The notes will be used for research purposes only. Only Dr. Gitte Lindgaard, my thesis supervisor, and myself may see these notes.

At this time, I would take this opportunity to thank you for your participation.

Do you have any questions before we begin?

Appendix I

Task-Analysis for IVS

Activity	Assembling an order → Motive = paycheck, provide for kids
Actions	<p>Check board → Goal → to see where they are working</p> <p>Get Long-John (LJ) → to get a good LJ – assemblers get to know what long-johns are faster than others</p> <p>Get Device → to get a good IVS – assemblers get to know what units are less problematic than others</p> <p>Logon to WMS → to get paid (like punching in)</p> <p>Logon to IVS → to get the first order</p> <p>Assemble → to meet quota</p> <p>Wrap → to keep the load secure</p> <p>Drop-off → to finish order and get new order</p> <p>Log off → to go on break or leave for the day</p> <p>Leaving for the day → to get out of the warehouse</p>
Operations	<ol style="list-style-type: none"> 1. Check Board <ol style="list-style-type: none"> 1.1. Walk over to board 1.2. Read name and department 2. Get Long-John <ol style="list-style-type: none"> 2.1. Search/scan for LJ (usually in staging area near grocery supervisor's office or in staging area near meat/freezer supervisor's office). 2.2. Drive it to the meat department <ol style="list-style-type: none"> 2.2.1. Driving a LJ consists of standing on the front platform, rotating the controls forward for forward and rotating the controls backward for reverse. 3. Get Device <ol style="list-style-type: none"> 3.1. Get keys from manager's drawer 3.2. Open personal locker 3.3. Take battery back out of the recharger stored in locker 3.4. If a device is there, put battery into device 3.5. Check to see if the battery/device is working 3.6. If the device is not there, open other lockers to find one. Once one is found, follow step 3.3. 3.7. If the battery is working, attach headset to the device and put it on head <ol style="list-style-type: none"> 3.7.1. adjust headpiece and microphone as needed 3.8. If a headset is not in private locker, open other lockers to find one. Once one is found, follow step 3.6. 3.9. Close door and lock the locker 3.10. Replace keys in manager's drawer

<p>◇ = system prompt</p>	<p>4. Logon to device</p> <p>4.1. <PLEASE SAY YOUR LOGON PHRASE> <i>John Doe, picking</i></p> <p>4.2. <SAY DEPARTMENT> <i>"meat department"</i></p> <p>4.3. <SAY VEHICLE TYPE> <i>"vehicle delta whiskey mike"</i></p> <p>4.4. <SAY VEHICLE ID> <i>"vehicle delta papa 101"</i></p> <p>4.5. <START PICKING> <i>"picking confirmed"</i></p> <p>4.6. The user adjusts the volume by manually pressing a + or – button on the headset cord. The system says <SAMPLING NOISE, PLEASE BE QUIET>. The user waits for the next instruction from the system.</p>
	<p>5. Start assembling</p> <p>5.1. System tells assembler the number of palettes, number of items to pick and cubic inches of load.</p> <p>5.1.1. To get a pick task location range, user asks the system <i>what range?</i></p> <p>5.2. Assembler gets onto LJ and drives to first location</p> <p>5.2.1. <XX 1234, PICK 2></p> <p>5.3. Assembler stops LJ at XX 1234, to pick items</p> <p>5.3.1. Once item is picked (or during the lifting/putting task), the user says <i>"check XXX, grab 2 confirm"</i> (note: the product i.d. the system gives contains the isle and 4-digit number. The user confirms another digit, which is next to the 4-digit number.</p> <p>5.3.2. Assembler continues until order is complete.</p>
	<p>6. Wrap</p> <p>6.1. Once the pick tasks are completed, the system prompts the user to select a label printer <PRINTER LOCATION>, user says <i>"label printer, location ABC"</i>.</p> <p>6.2. The assembler drives to the printer location.</p> <p>6.3. If more than 1 palette, the assembler separates the loads so that the he can wrap each load is plastic wrap.</p> <p>6.3.1. Assembler drops the forks by pressing the down button on the LJ</p> <p>6.3.2. Drives forward so that only 1 palette is on the fork</p> <p>6.3.3. Picks up one palette with the fork by pressing up button on the LJ</p> <p>6.3.4. Drives forward to separate load</p> <p>6.4. Assembler holds roll of plastic wrap and walks around the load until the upper half of the load is secure – then rips plastic</p> <p>6.4.1. If two palettes, repeat 6.4.</p> <p>6.5. Assembler takes label from printer and sticks it on a palette.</p>
	<p>7. Drop-off</p> <p>7.1. Assembler drives the LJ to the staging area. The system prompts for the lane check ID/load ID <LANE XYZ>, user says <i>"check XYZ, load NNNN"</i>.</p> <p>7.2. Once the system as confirmed information, it prompts <START PICKING>, continue with step 5 to 7.</p>
	<p>8. Log off</p> <p>8.1. To log off, the user requests, <i>"switch to special menu"</i>. The system confirms <SPECIAL MENU>. The users says <i>"log me off"</i>, the system</p>

	<p>responds <OUT FOR THE DAY?>. At this point, the user can say, “<i>confirm temporary</i>” or “<i>confirm final</i>”.</p>
	<p>9. Leaving for the day</p> <p>9.1. If the assembler is at the beginning or middle of an order, the user breaks the pick list (order) by saying “<i>break pick list</i>”, system prompts <NOTIFY SUPERVISOR, CONFIRM BREAK>. (<u>note</u>: the assembler does not actually confirm with anybody, but responds to the system by saying “<i>break confirm</i>”.</p> <p>9.2. The user logs off the system (step 8.1 – “<i>confirm final</i>”).</p> <p>9.3. Get keys from manager’s drawer</p> <p>9.4. Open personal locker</p> <p>9.5. Take battery out of the unit</p> <p>9.6. Put battery back in the recharger stored in locker.</p> <p>9.7. Put headset in locker</p> <p>9.8. Close door and locks the locker</p> <p>9.9. Replace keys in manager’s drawer</p> <p>9.10. Log off of WMS</p>

Appendix J

Task-Analysis for Hand-Held

Activity	Assembling an order → Motive = paycheck
Actions	<p>Check board → Goal → to see where they are working</p> <p>Get Long-John (LJ) → to get a good LJ – assemblers get to know what long-johns are faster than others</p> <p>Get Device → to get a good hand-held – assemblers get to know what units are less problematic than others</p> <p>Logon to WMS → to get paid (like punching in)</p> <p>Logon to hand-held → to get the first order</p> <p>Assemble → to meet standards</p> <p>Wrap → to keep the load secure</p> <p>Drop-off to finish order and get new order</p> <p>Log off to go on break or leave for the day</p> <p>Leaving for the day to get out of the warehouse</p>
Operations	<ol style="list-style-type: none"> 1. Check Board <ol style="list-style-type: none"> 1.1. Walk over to board 1.2. Read name and department 2. Get Long-John <ol style="list-style-type: none"> 2.1. Search/scan for LJ (usually in staging area near grocery supervisor's office or in staging area near meat/freezer supervisor's office). 2.2. Drive it to the department <ol style="list-style-type: none"> 2.2.1. Driving a LJ consists of standing on the front platform, rotating the controls forward for forward and rotating the controls backward for reverse. 3. Get Device <ol style="list-style-type: none"> 3.1. Go to supervisor's office window/unit storage area (there is usually a line-up) 3.2. The assembler gives his name to the supervisor (if a new employee) and he is working for the shift <ol style="list-style-type: none"> 3.2.1. supervisor gets hand-held device (which are stored in a charger unit) from storage area 3.2.2. supervisor checks to see if the scanner and device is working 3.2.3. supervisor logs the system to the user on tracking software 3.2.4. supervisor hands the system over to the assembler 3.3. Assembler walks away from the window and is ready to logon

◇ = system prompt	<p>4. Logon to device</p> <p>4.1. User keys in Alt F1 to get logon menu</p> <p>4.2. <ID> user types in JDOE</p> <p>4.3. <PSW> user types in password</p> <p>4.4. <VEHICLE TYPE> user types in vehicle type</p> <p>4.5. <LOCATION> user types in nearest WMS workstation/printer location.</p> <p>4.6. <VEHICLE ID> user types in vehicle i.d. or scans barcode on vehicle</p> <p>4.7. New menu – category menu</p> <p>4.7.1. A–INBOUND; B–OUTBOUND; C–INQUIRY, assembler types B for outbound</p> <p>4.8. New menu – job</p> <p>4.8.1. A–ASSEMBLY; B–FORKLIFT; C–SHIP/RECEIVING, assembler types A for assembly</p> <p>4.9. Assembler keys F1 to get his pick list.</p>
	<p>5. Start assembling</p> <p>5.1. System tells assembler the store they are picking for, the number of pallettes, number of items to pick and cubic inches of load.</p> <p>5.2. Assembler gets onto LJ and drives to first location</p> <p>5.2.1. <XX 1234 2></p> <p>5.3. Assembler stops LJ at XX 1234, to pick 2 items</p> <p>5.3.1. the user scans the barcode to confirm item either before picking the item or after (<u>note</u>: no quantity input is required)</p> <p>5.3.2. Assembler continues steps 5.3 until order is complete.</p>
	<p>6. Wrap</p> <p>6.1. Once the pick tasks are completed, the system prompts the user to select a label printer.</p> <p>6.2. The assembler drives to any printer location.</p> <p>6.3. The user scans the printer barcode</p> <p>6.4. If more than 1 palette, the assembler separates the loads so that the he can wrap each load in plastic wrap.</p> <p>9.10.1. Assembler drops the forks by pressing the down button on the LJ</p> <p>6.4.1. Drives forward so that only 1 palette is on the fork</p> <p>6.4.2. Picks up one palette with the fork by pressing up button on the LJ</p> <p>6.4.3. Drives forward to separate load</p> <p>6.5. If only 1 palette, follow steps 6.6.</p> <p>6.6. Assembler holds roll of plastic wrap and walks around the load until the upper half of the load is secure – then rips plastic</p> <p>6.6.1. If two pallettes, repeat 6.4.</p> <p>6.7. Assembler takes label from printer and sticks it on load.</p>
	<p>7. Drop-off</p> <p>7.1. Assembler drives the LJ to the staging area. The system prompts for the lane ID. User types in lane i.d. If the user wants to continue picking, he keys F1 to get another pick list and continues with steps 5 through 7.</p>

	8. Log off 8.1. User keys in Alt-0 to log off. System response <FOR THE DAY, Y / N?> User keys in Y or N depending on circumstance.
	9. Leaving for the day 9.1. If assembler is at the beginning or middle of an order, the user breaks the pick list (order) by keying Alt-3 – then follows steps 6 through 8. 9.2. The user logs off the system for the day (step 8.1). 9.3. The user drives the LJ to the staging area (near supervisor's office) 9.4. The users drops off the device at the supervisor's office window/unit storage area 9.5. The assembler logs off of WMS