Ludwig, T. D., & Goomas, D. T. (2007). Performance, Accuracy, Data Delivery, and Feedback Methods in Order Selection: A Comparison of Voice, Handheld, and Paper Technologies. *Journal of Organizational Behavior Management*, 27(1), 69-107. doi:10.1300/J075v27n01_03 Version off record published by Published by Taylor & Francis and is available online at: http://www.informaworld.com/ (ISSN: 0160-8061)

Keywords: auditory feedback | human performance technology | immediate feedback | Organizational behavior management | visual feedback

Performance, Accuracy, Data Delivery, and Feedback Methods in Order Selection: A Comparison of Voice, Handheld, and Paper Technologies

Timothy D. Ludwig and David T. Goomas

ABSTRACT

A field study was conducted in auto-parts alter-market distribution centers where selectors used handheld computers to receive instructions and feedback about their product selection process. A wireless voice-interaction technology was then implemented in a multiple baseline fashion across three departments of a warehouse (N = 14) and was associated with a 17% increase in productivity over the previously implemented handheld scanning technology of the baseline condition and comparison departments that continued to use handheld scanner technology. Selection accuracy was nearly identical for voice (99.55%) and handheld (99.80%) technology. But, both were associated with substantially higher selection accuracy than a paper-based method (96.50%). Accuracy with voice instruction delivery, however, was most vulnerable whenever upstream events (i.e., processes that occur before the selection process such as receiving, replenishment, and inventory control) resulted in the wrong product being in the selection location. The implications and limitations that arise with these technologies are discussed as well as the expanded role of the Organizational Behavior Management professional.

ARTICLE

INTRODUCTION

Companies that operate warehouses continually strive to minimize costs in their supply chains. They are constantly challenged to improve productivity (Goomas & Ludwig, 2007), reduce labor costs and increase selection accuracy (Bateman & Ludwig, 2003; Berger & Ludwig, 2007) in order to decrease operational costs while insuring customer satisfaction. Order selection is one of the most labor-intensive functions in a warehouse. When a customer order is received by the warehouse it is converted to paper-based selection guide and given to employees called "selectors." Selectors use the paper-based selection guide to visit various selection locations throughout a warehouse retrieving (i.e., selecting) products in accordance with their selection guides. The completed order is then delivered to a loading dock where it is prepared for transport. The activity sequence is then repeated for the next store order.

Selector errors and other selector behavior can increase costs of order fulfillment. Selectors can damage a product, select the wrong product, select too many or too few units of a product, or fail to select a product. All such errors result in financial costs because customers must be refunded or given credits when errors occur. It is necessary, therefore, to manage employee behaviors to maintain desired levels of both productivity and quality.

Three-Term Contingency Delivery in Warehouses

In a warehouse environment, three-term environmental contingencies (i.e., antecedents, behaviors, and consequences; Poling & Braatz, 2000) promote and maintain selectors' behaviors (Luthans & Kreitner, 1985) that result in accurate and timely order selections. These behaviors include reading their instructions, driving to the correct location, comparing their information with the information on the physical products and location in front of them, and selecting the right amount of product. Selectors must engage in all of these behaviors while avoiding behaviors that may result in errors or delays such as, respectively, skipping items, selecting too many or too few items, and talking with fellow employees.

Antecedents prompt the correct behaviors and indicate when performance will be followed by a consequence. Selectors, for example, are given a paper list of products to select from the warehouse. The list serves as an antecedent to the subsequent behaviors of selecting the products. Other antecedents in the warehouse were posted identifying information for aisles, locations, and products. In this system, these visual cues served as the only environmental stimuli available to selectors as they progressed through their order (Berger & Ludwig, 2007; Goomas & Ludwig, 2007). Additionally, workplace goals also provided antecedents to the selectors indicating the rate or accuracy of behavior and the outcomes that would result in a favorable consequence.

A consequence may follow the sequence of behaviors in a work process contingent on the successful (or unsuccessful) completion of the behavior sequence. A consequence might be a reward such as a monetary payout to the worker (Bateman & Ludwig, 2003; Goomas & Ludwig, 2007) analogous to varying types of schedules of reinforcement (Hantula, 2000). Complex contingencies in the workplace may make consequences contingent on completing a certain number of products within a certain period of time, which is equivalent to the concept of *productivity* (Deming, 1982; Sink & Tuttle, 1989). However, the contingency may also be based on the *quality* of the behaviors. A quality behavior is one without errors in design, timing, accuracy, or physical attributes (Deming, 1982; Sink & Tuttle, 1989).

Brethower (2000), Deming (1982), Gilbert (1978), and Sink and Tuttle (1989) point out that the quality of the final product is a function of the quality of the behaviors that occur during the work process. In industrial jobs, errors often occur when a work process is not followed. Behaviors that are skipped in the work process cause errors as do behaviors that deviate from the work process. Often the consequences of these errors are far removed from the time (delayed) and place when and where the deviant behaviors occur. Thus, consequences of these behaviors fail to either eliminate (punish) the deviant behavior or promote (reinforce) occurrences of correct behaviors.

Distal Contingencies

In a contingency, consequences may be temporally remote from their behaviors owing to the length of the work process and/or the structure of the contingency. For example, monetary consequences of behavior may not be received by employees until the end of each work week, and bonuses earned during that week might not be paid until the end of yet another week. Bateman and Ludwig (2003) described an incentive program under which employees earned money contingent upon each case of product they selected and lost money contingent upon selection errors. However, the ultimate tangible consequences of effective order selections and selection errors were not experienced until employees saw their results in their next paycheck. Some consequences may be so far removed in time from the original behaviors that produced them that they fail to directly regulate employees' performance-related behavior. Although the performance consequence contingency is “real” or an empirical fact, it simply fails to have an effect on performance-related behavior (Malott, 1992).

Immediate Feedback

In Berger and Ludwig (2007) and Goomas and Ludwig (2007), we argued that increased productivity and accuracy was largely owing to robust effects of immediate feedback to employees regarding their performance in terms of speed and accuracy of product selection. Few direct comparisons have been made between immediate and delayed feedback. Most studies report on feedback that had been delivered on a daily or weekly schedule to employees (Alvero et al., 2001; Balcazar, Hopkins,&Suarez, 1986; Leivo, 2001). Indeed, only a small number of studies have examined the relative effectiveness of frequent and less frequent feedback on participants' performances (Alavosius & Sulzer-Azaroff, 1990; Dihoff, Brosvic, Epstein, & Cook, 2004; Mason & Redmon, 1993).

Based on their experiences in workplace environments, Sulzer-Azaroff and Mayer (1991) concluded that providing immediate consequences in these settings is often impractical and nearly impossible.
More recently Dihoff et al. (2004) concluded that, in general, it is more difficult to deliver consequences immediately in applied settings. The ability to deliver immediate feedback to a large workforce often requires expensive technologies, both in terms of hardware and software.
In the workplace, supervisors attempting to provide feedback immediately would have to be present for every work unit performed by each associate, which of course, is not practical, given the other duties and responsibilities supervisors have to carry out. On the other hand, even if expensive, a technological solution to this perennial problem may be attractive if gains in workforce productivity are expected to equal or exceed the costs of acquiring and training employees in the use of technology-based feedback systems.

Experimenters and practitioners have begun to use technology as a means of delivering immediate feedback in applied settings (Berger & Ludwig, 2007; Dihoff et al., 2004; Epstein, Lazarus, Calvano, Matthews, Hendel, Epstein & Brosvic, 2002; Goomas & Ludwig, 2007; Terrel, 1990). Results of their studies suggest that using technology to provide frequent feedback immediately following a behavior substantially improves employees' performance in terms of both productivity and accuracy.
Technological solutions to the problem regarding how to deliver immediate and accurate feedback to employees present Organizational Behavior Management professionals with tremendous opportunities and challenges.

Technology has played an important role in warehouse management, beginning with the use of wireless handheld computers to direct the workflow (Hill, 1996). More recently, manufacturing and distribution trade journals such as *DC Velocity* (Johnson, 2005), *Logistics Management* (Lacefield, 2004), and *Supermarket News* (Parks, 2004) have reported that technologies such as handheld scanning and speech recognition systems improve productivity and accuracy in labor-intensive industrial tasks such as order selection in manufacturing and distribution operations.

Immediate Visual and Auditory Contingencies

Using Handheld Wireless Computers

Wireless handheld computers use a radio frequency (RF) system to retrieve information from company mainframes that can then be presented to selectors on a screen. When selecting each item, selectors retrieve their handheld wireless computer from its holster, select the item from the location, scan the item's bar code, enter the quantity selected, and return the handheld unit to the holster. Over the course of an 8-hour shift, an order selector might draw, handle and holster the handheld unit 300 to 700 times.

The three-term environmental contingency created by handheld computers insures relatively immediate temporal relations among the antecedents, behavior, and consequences of finding and selecting items to complete a customer's order. During the order selection process, the handheld computer presents a strict selection sequence for the product items just before the selector has to engage in selection behavior. These real-time prompts from the handheld computer serve as antecedents for subsequent behaviors telling the selector what product to get, how many, and where to find it. Handheld computers can also be modified to provide more complex antecedents such as goal times and performance feedback (Goomas & Ludwig, 2007).

Handheld computers are typically configured to scan a product's bar coded UPC (Universal Product Code) via an infrared beam. The computer compares the UPC scanned with the correct UPC. A staccato beep informs selectors that they successfully scanned a bar code. The handheld computer is programmed to emit a second beep with a different tone if the UPC scanned doesn't match the UPC of the requested case of product. The auditory feedback of the second beep serves as an immediate consequence of incorrect behavior, and should forestall occurrence of the next behavior in the behavior chain until the correct product is selected.

Goomas and Ludwig (2007) reported an immediate 24% productivity increase with the implementation of handheld computers and engineered work standard goals. With this increase, employees were able to earn the incentives that they had not been able to achieve prior to the implementation even though the incentive contingencies had been in place for some time.

Immediate Auditory Feedback
Using Voice-Directed Headset Computers

In a "voice selection" system, the order selectors wear a battery-powered waist unit and a headset with an attached microphone that connects via radio frequency to a warehouse management system. The order locations and quantities are spoken to selectors by the computer that prompts selectors to drive to the correct location and select a certain number of the product. They can comply with these instructions without having to use their hands or eyes to hold and view paper order sheets or handheld computers.

Upon arrival at the product location, selectors read a two number "check digit" taped to the product supply bin at that location. The digits read would be compared with the digits listed in the computer databank for the correct location. If the correct check digits are uttered, the unit states the ordered case quantity (e.g., "select three"). This statement evokes the next behavior in the behavior sequence, namely for the selector to transfer three cases from the location onto the pallet used to collect product to fulfill the customer order.

If a selector speaks the wrong check digits while standing in front of a wrong location the system responds by repeating the correct location information. Hence, a selector comes in contact with a consequence of his/her behavior immediately upon arriving at a location (the end of one behavior) but before engaging in the next behavior in the behavior sequence (selecting the items). Additionally, the voice technology will not present the number of units to be selected from the location until the correct check digits are spoken in the presence of the correct location.

Berger and Ludwig (2007) recognized this as an additional consequence beyond simple feedback whereby the selector has to complete the previous behavior sequence correctly before getting the next prompt. Berger and Ludwig reported a 62% decrease in the number of selection errors in a food distribution warehouse when management implemented voice technology as compared with the paper selection system it replaced. As would be expected, in their study, voice technology had the greatest impact on the employees who where previously making the most errors and therefore had the greatest potential for improving performance or PIP (Gilbert, 1978). Error rates among the lowest performers dropped from 10.17 per 1000 cases during baseline with paper-based customer order, or select, sheet technology to 2.04 per 1000 cases following implementation of voice technology.

Handheld Compared with Voice Computer Technology

The environmental stimuli available to selectors are identical for both technologies, namely, the aisle postings and location numbers and product identifying information on the cases. Handhelds and voice headsets provide immediate auditory feedback (i.e., beep or voice). Handhelds provide immediate visual feedback displayed on the handheld screen.

Both scanning and voice technologies offer a powerful contingency in that the order selector is not presented with the next product location prompt until the successful completion of previous product selection has been verified. Computer training research indicates that requiring trainees to provide a correct response before moving on to the next item substantially decreases errors (Alessi & Trollip, 1985; Jonassen, Tessmer, & Hannum, 1999; Terrel, 1990).

Reports from vendors, trade journals, and logistics consultants alike (e.g., Lacewell, 2004; Miller, 2004; Wulfraat, 2002) state that voice-activated computers, using headsets to deliver oral instructions and feedback, provide greater performance outcomes than handheld technologies. Productivity and accuracy are the outcomes of performance-related behaviors upon which financial results of manufacturing plants, warehouses, and distribution companies depend.

Keeney (1994) described *productivity* in terms of how much output a worker produces per unit of input. For example, in manufacturing and warehouse settings, the output of selectors is often defined as the number of cases selected and delivered to the loading area during some duration of time. Input is often defined as labor costs usually recognized as a unit of time, hour, day, week and so on. Therefore, the typical definition of productivity in a warehouse setting is *cases per labor hour*. Cases per hour is a measure that can be applied to many different levels of analysis including the individual worker, work group, or the entire workforce. Increases in cases per labor hour benefits the company by reducing staffing, over-time, and associated labor costs.

When comparing productivity of selectors using paper sheets to voice selection technology, Miller (2004) reported 3% to 4% productivity increases across departments of a food distribution warehouse. Miller reported 8-15% more productivity from voice selection compared with handheld scan selection technology. The ergonomics of voice weighs heavily in favor of implementing this technology because over the course of an 8-hour shift, the order selector may draw, view, and holster the handheld unit 300 to 700 times when using the handheld technology. These results would seem to justify the extra cost of implementing voice technology over handheld technology within distribution centers and warehouses.

Voice technology vendors and a number of logistics consultants also contend voice technology results in higher selection accuracy (i.e., lower errors) than handheld computers (e.g., Wulfraat, 2002). Indeed, Miller (2004) reported an overall order selection error rate decrease of 11% fewer shortages (a desired product absent from the order) and a 25% reduction in line errors (selecting a case which was not part of the store order) when using voice selection instead of handheld selection technology.

A review of published research regarding effectiveness of voice selection relative to handheld technology yielded no direct comparisons of the two. The purpose of this field report was to evaluate the impact on selector productivity and accuracy as handheld computer scanners were supplanted by voice-directed wireless computers in an auto-parts distribution warehouse. Based on the literature reviewed here, productivity and accuracy would be expected to improve when voice technology supplanted handheld computer scanning technology.

METHODS

Participants

Participants were order selectors at two Distribution Centers. The two distribution centers were organized similarly and their selection tasks and workflow were identical. Distribution Center A was in New York state and was the site where some of the product departments began using the voice technology. At Distribution Center A there were 14 order selectors (four in Batteries, four in Tires, and six in Accessories; all male) who converted from using handheld computers during baseline to using voice technology during the intervention. This group of 14 served as the experimental group. A comparison group of seven order selectors (six male and one female) selected shocks and struts from paper sheets throughout the study. Participant ages ranged from 22 to 32 years (M = 25.9) and had worked in this particular warehouse ranging from 6 months to 4.25 years, (M = 1.67 years).

At Distribution Center B, located in Indiana, 11 order selectors (three in Batteries, four in Tires, and four in Accessories) were used as an additional comparison group. All were males, except for one female in Accessories. Participant ages ranged from 21 to 31 years (M = 25.1) and had worked in this particular warehouse ranging from 4 months to 3.50 years, (M = 2.33 years). Order selectors in this distribution center used handheld computers throughout the study while selecting the same products for the same parent company. All order selectors observed in this study were employed throughout all phases of the study.

Setting

The study was conducted at two auto-parts distribution centers, named A and B in this study. When store orders were assigned to selectors, the warehouse management system (WMS; a computer-based information management system) directed the specific selecting sequence within each retail store's order for individual selectors based on the sequencing of the product locations within the aisles (approximately 75 yards long) of each warehouse. Thus store orders were configured to minimize travel and optimize selecting density within a distribution center section (i.e., batteries, tires, accessories, shocks, and struts).

Battery selectors were required to select an average quota of 145 batteries per hour, tire selectors were required to select an average quota of 140 tires per hour, and accessory and shocks and struts selectors were required to select an average quota of 180 units per hour. These quotas were established by the corporate Industrial Engineer once a year and were identical across all distribution centers. A daily printing of the units selected during the previous day's work was posted in the break room before selectors arrived for work the next day. Each day there was a meeting of all selectors at the start of the shift during which the supervisors reminded selectors of their selecting quotas, stating the number of units that should be selected and clean-up duties to be performed at the end of their shift.

Selectors who regularly failed to meet the quotas were subject to progressive disciplinary actions. Failure to achieve the published quotas over a 1-week period resulted in a verbal warning. A second failure within 3 months resulted in a written probation for 3 months. A third failure within the probationary period resulted in dismissal at that time. Teams that exceeded quotas were given bonuses. If the average performance of the team exceeded the minimum quota by 5% for a month, a bonus of $200 was added to each team member's paycheck. Quotas exceeded by 7% resulted in a bonus of $300. The employee(s) who individually exceeded the quota by 5% or 7% did not receive the bonus if the entire team average failed to exceed the quota at either of the two specified levels.

Task

A workflow diagram for each of the groups is shown in Figure 1. All selectors, regardless of whether they selected store orders exclusively by paper or handheld or transitioning from handheld to voice computer got on a pallet jack, went to the pallet pool (P) area and retrieved a wooden pallet (tire selectors used tire carts). They headed toward their assigned selection section (S) and began to select products, one product line at a time, as directed by the paper sheet, handheld device, or voice computer. Upon completion of the order, the selector wrapped the pallet in plastic stretch-wrap and placed the pallet at the drop-off (D) point, usually a door. Customer orders ranged from 15 to 22 pallets and tire carts, averaging 45-55 cubic feet per pallet. These orders ranged from 3,800 to 5,000 units with each containing a product mix of tires, accessories, batteries, belts, rotors, brakes, hoses, alternators, etc.

Dependent Variables

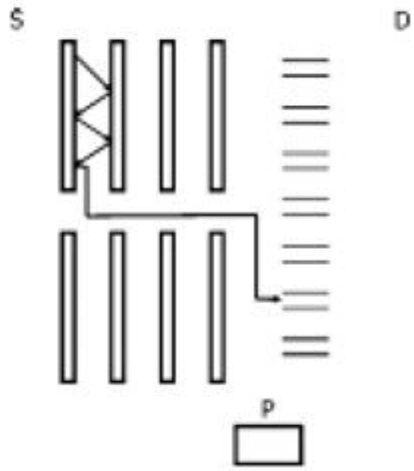
Selection productivity. The dependent variable for selection productivity was calculated as departmental average units (DAU) within the WMSsystem.A unit could be a single battery, a single tire, a single mirror, or a single case. The formula was as follows:

DAU = total units selected/total hours the department was active for the day.

The DAU was collected in the labor report submitted by shift supervisors at their computers. The report included the number of units selected by each associate over the actual time spent selecting, excluding lunch and two company-paid 15-minute breaks, in their department. The host company could print the labor report containing DAU by department across its distribution centers allowing for easy comparison for the same type of work between distribution centers as well as an enterprise view, across all departments and across all distribution centers.

Selection accuracy. The dependent variables for selection accuracy were determined during an audit of completed pallets (or totes) after the

FIGURE 1. Warehouse Diagram for Order Selector Selecting Products from Selection Locations (S) and Dropping Pallet (P) off at the Drop-Off Point (D)



order had been selected. Pallets audited were randomly selected by the Loss Prevention manager so selectors did not know when what they selected might be audited. Auditing of orders usually took place in 3rd shift between 11:00 p.m. and 4:00 a.m. Loss Prevention auditors compared actual items selected with the original stores' orders as a check on order selection accuracy. The host company performed daily audits using handheld wireless computers on approximately 5% of the orders. An audit exception report included calculation of the selection accuracy through a comparison of UPC codes scanned on the pallet and the UPC codes required in the customer order. The exception report listed two types of errors: line errors and overs/shorts.

Line errors. The host company defined the selecting of a wrong case to be *line errors* when: (1) a scanned UPC did not match the item that should have been selected for inclusions in the order, and (2) an item that should have been selected and was not present on the pallet (or tote) for which there was no scan for the auditor to make.

In most cases two-line errors occurred every time a product was incorrectly selected. For example, if a selector selected product A instead of product B and the auditor scanned the UPC for product A then it did not match the order. The audit report depicted one-line error for product A. However, because product B was missing the auditor did not scan product B's UPC. Thus a second line error was recorded for the missing scan of product B. To the host company, the first error was for an item that would have shipped to the store that the store didn't order; the second error represented a nonsale. Line errors were aggregated using the following calculation:

> Line errors = total audited line errors/total audited lines selected.

Overs/Shorts. If selectors selected too many cases of the correct item or if selectors selected too few units of the correct item, the error showed up as an *overs/shorts* error. For example, an over occurred when instead of selecting 2 fuses as ordered, 3 fuses were selected. Conversely, a short occurred when, instead of selecting 3 fuses, the selector selected 2 fuses. Overs and shorts were aggregated using the following calculation:

> Overs/shorts = absolute value of audited unit errors/total audited units selected.

Design

A multiple baseline design across experimental departments (i.e., experimental departments: Batteries, Tires, and Accessories) with nontreatment comparison departments (i.e., comparison departments: Batteries, Tires, Accessories, and Shocks and Struts) was used to contrast the voice selection system with existing paper-based and handheld computer selection systems. Baseline measures were collected at both distribution centers (i.e., Warehouses A & B) prior to the implementation of voice order selection. During baseline, both experimental and comparison selectors in batteries, tires, and accessories completed their orders using handheld computers. However, order selectors in struts and shocks completed their orders using paper-based sheets.

Following a 10-day baseline phase, voice technology was implemented at Warehouse A in the Battery and Tire departments first. Sixteen working days later, the Accessory department implemented voice technology (i.e., day 26). Productivity and accuracy data continued to be recorded for a total of 20 working days after the Accessories department implemented voice selection. The comparison department selecting struts and shocks in Warehouse A continued using paper-based selection throughout the study. The Battery, Tire, and Accessory departments in Warehouse B continued using handheld computers throughout the study. Table 1 shows the phases and number of participants for all three selection methods between two distribution centers across seven departments.

Selection Methods Contrasted in this Study

Paper-based selection. Selectors in the struts and shocks department of Warehouse A used paper-based selection systems to direct them through their work process. Selectors were given a sheet that contained a paper print-out of the order. Lines on the sheet depicted the item location, item number, the item description, pack (the number of units inside

the case), manufacturer part number, and the quantity to select. The paper sheets were similar across all distribution centers.
If there was a shortage of a product, selectors circled the item number, crossed out the printed quantity and wrote in the quantity selected.

If the selection location was empty, selectors wrote a zero next to the ordered quantity number. Completed sheets were returned to supervisors who would then direct an employee to locate any reserves in storage

TABLE 1. Phases and Number of Participants for All Three Selection Methods Across Seven Departments in Two Distribution Centers (DC)

Departments	Baseline	Phase 1	Phase 2	Notes
Batteries (n = 4) Tires (n = 4)	Handheld	Voice	Voice	Experimental Group Warehouse A
Accessories (n = 6)	Handheld	Handheld	Voice	Experimental Group Warehouse A
Batteries (n = 3) Tires (n = 4) Accessories (n = 4)	Handheld	Handheld	Handheld	Comparison Group Warehouse B
Shocks and struts (n = 7)	Paper	Paper	Paper	Comparison Group Warehouse B

areas, replenish the missing product into the selection location, and pick the ordered quantity.

The workflow for selectors using paper lists was as follows:

- receive sheet from supervisors, based on their assigned section in the warehouse;
- read information about the first item on the sheet;
- drive the pallet jack to the location indicated on the sheet;
- pick the quantity indicated on the sheet;
- place item(s) on a pallet;
- check agreement between the description and part number on the case and the sheet description and part number;
- place a check mark next to the item on the sheet;
- continue to repeat this sequence of tasks until the end of the sheet was reached.

Handheld computers. Selectors in the battery, tire, and accessory departments in both distribution centers used handheld computer systems during baseline. The handheld wireless computers used by the host company were the Intermec Model CK30 pictured in Figure 2. Order selectors wore a holster around their waist where the handheld computer was placed. The handheld was outfitted with a screen and a scanner. A keypad permitted information entry into the handheld unit.

FIGURE 2. Wireless Handheld Unit Used for Order Selection (also used for store audits)

Riding a pallet jack with a pallet, order selectors responded to the directions presented on the wireless handheld screen depicted in Figure 3.

Key lines of information for this study were as follows:

- line 6 displayed the location of the product to be selected (e.g., CD0712);
- line 8 displayed the order quantity followed by an enterable field for the selectors to key in the quantity selected starting in column 19 through column 20 (see gray area);
- line 9 displayed the product number;
- line 11 displayed the product description;
- line 15 displayed the next location in the order.

Handheld computer screens were identical across distribution centers in this study.

Order information on the handheld computers was identical to the order line on a paper sheet. Unlike paper sheets, handheld computers only displayed information for the item currently being selected.

The work flow repeated by selectors for each product in a customer order was as stated here:

- sign on to the handheld with logon and password;
- look at the location and item on the computer screen;
- drive the pallet jack to the location indicated on the screen;
- select quantity shown on the screen;
- retrieve handheld computer from holster;
- scan the UPC of the item retrieved from the location–listen for beep, indicating successful barcode scan;
- if there was a UPC mismatch (described below) the handheld computer would emit a second beep and the selector would need to achieve a UPC match before getting the prompt for the next step

(the selector could also “skip” to the next item if the mismatch was caused by an inventory control problem outside of their control);

- if no UPC mismatch, retrieve the number of units(s) shown on the screen and place units on pallet;
- enter the number of unit(s) selected and press the “enter” key;
- if there was a quantity mismatch (described later) the handheld computer would emit a beep and the selector would need to address the quantity mismatch before getting the prompt for the next step (the selector could also “skip” to the next item if the mismatch was caused by an inventory control problem outside of their control);
- if no quantity mismatch, place wireless handheld computer back in holster;
- continue this process until the screen message indicated “end of assignment.”

When errors occurred the handhelds were configured to emit two beeps alerting selectors of the following events.

UPC mismatch. If the scanned UPC did not match the ordered UPC code the handheld computer emitted a second beep. This mismatch occurred because the selector went to the wrong location or the wrong product was in the correct location. The selector then had to find the right location and scan the new item for a correct UPC code. Selectors could not continue to the next item until the quantity mismatch was corrected. If selectors came to the correct location that had the *wrong* product in the location, they would enter a “0” in the quantity field. The error “quantity mismatch” would appear with an option to enter “Y” when prompted to “Continue?” Entering a “Y” allowed them to continue to the next item. If the UPC scanned matched the bar code of the item on the order, the handheld computer then performed quantity checks.

Quantity mismatch. After the selector entered the quantity of the item selected a comparison of the quantity ordered (line 8) to the quantityentered (line 8, columns 19 and 20) was conducted by the computer.
If the two counts differed the message “quantity mismatch” appeared in the handheld computer screen (line 1) along with the second beep. Selectors could not continue to the next item until the quantity mismatch was addressed.

If selectors came to the correct location that had *less* than the number of units required to fill the order, they would enter the number of correct units they actually selected. The system disallowed inputting a count that was *more* than the units required to fill the order. The error “quantity mismatch” would appear with the only option being to re-enter the correct quantity.

When items were skipped for either UPC or quantity mismatches beyond the selectors’ control, the shipping office was sent an electronic record identifying product(s) that had been shorted because of incorrect quantities or wrong items. These inventory control issues could then be rectified.

Voice selection. After the baseline phase the Battery, Tire, and Accessory departments at the experimental distribution center were switched from handheld computers to voice selection. Selectors wore a headset, which was connected to a battery pack and wireless computer secured around their waist. The headset included a single earpiece so that the selectors could hear announcements, voices, and other workplace sounds along with a noise-canceling adjustable microphone (see Figure 4). The Talkman (a registered trademark of Vocollect, www. vocollect.com) unit communicated with the WMS via radio frequency. The technology relied on “speech recognition” as well as “speech synthesis” computer software that interpreted speech into text and enabled a voice computer to talk to its operator (Byford, 2002).

The voice technology required that a “check digit” be posted at each location in the warehouse (Figure 5) affixed on the horizontal cross-bar of the rack holding products. The first label was the warehouse location (e.g., 4402721), and the second label presented the “check digits” (e.g., 21). Rather than scanning the UPC with the handheld computer, order selectors were asked to utter two check digits posted on the horizontal cross-bar of the destination location to verify that they were at the correct location.

FIGURE 4. The Wireless, Wearable Voice System

FIGURE 5. Location Label with Check Digits

The work flow repeated by selectors for each product in a customer order was:

- "sign in" to the voice system and work was transferred from the WMS to each selector's voice computer based on their assigned section;
- ask for the first item by saying "ready" into the headset;
- listen to item location (For example, a selector might hear the select location, "four four zero two seven two one" representing aisle 44, bay 027, level 2, and location 1);
- drive the pallet jack to the location heard via the headset;
- read into microphone the check digits posted on the horizontal cross-bar;
- if there was a check digit mismatch (described below) the voice system would restate the correct location and the selector would need to achieve a check digit match before getting the prompt for the next step;
- if correct, listen to voice unit's response directing "select (number of units; e.g., 'select three')";
- select number of item(s) heard in the headset;
- place item(s) on pallet;
- state into microphone the item(s) when selected (e.g., "three");
- if there was a quantity mismatch (described later) the voice system would restate the correct quantity and the selector would have to address the quantity mismatch before getting the prompt for the next step (the selector could also "skip" to the next item if the mismatch was caused by an inventory control problem outside of their control);
- listen to new location heard in the headset;
- continue this process until directed to take the pallet to a staging location.

The following events for voice technology occurred first for check digit mismatches followed by quantity checks.

Check digit mismatches. If the check digits voiced by order selectors were incorrect or if order selectors did not articulate the digits properly, the voice system did not continue with the command directing the quantity of the item to be selected. Instead the voice system repeated the location prompt to selectors. Then selectors were to go to the correct location, read the check digits of the location specified and verify they were now at the correct location. If they read the correct check digits they were then given the selection quantity and the process continued with a series of quantity checks.

Quantity mismatch. After the selector spoke the quantity of the item selected, a comparison of the quantity ordered to the quantity spoken was conducted by the computer. If the quantity uttered exceeded the quantity ordered, the voice system stated "You said (spoken quantity), only asked for (select quantity). Try again." After a correct utterance of the selection quantity, the next location was presented. Selectors could not continue to the next item until the quantity mismatch was corrected.

If selectors came to the correct location that had less than the number of units required to fill, the order selectors would state the number of correct units they actually selected. The voice system responded “You said (spoken quantity), asked for (selection quantity). Is this a short product?” If the selector uttered “yes,” the application created an electronic record identifying the product as having been shorted, viewable in the shipping office, and the next location was presented. The selector could also skip an item in the event the wrong item was in the location or access to the aisle was prevented by equipment, breakage or spillage that prevented travel to the area. In this case the selector stated “skip slot” and the next location was presented. Later, the selector was directed to go back and select skipped items. If, on this second try, the selector uttered a quantity less than the ordered quantity, the application created an electronic record identifying the product had been skipped, viewable in the shipping office, and the next location was presented.

When items were skipped for mismatches beyond the selectors’ control, the shipping office was sent an electronic record identifying product(s) that had been shorted because of incorrect quantities or wrong items. These inventory control issues could then be rectified.

Implementation of voice system. Shift meeting announcements occurred 1 week before the assigned date the battery, tire, and accessory departments were to transition from handheld selection to voice selection. On the day of voice implementation at the beginning of the 3:00 p.m. shift, the department manager randomly asked a selector to report to the shipping office for voice template set-up and training, while the remaining associates within the department continued to select via the handheld computer.

Every selector in a department was transitioned to voice selection on the same day. A trainer assisted getting the equipment (headset and battery pack) operational for each selector and helped each selector set-up of the “voice template” so the system could understand the selectors’ verbalizations. Selectors’ voice pattern was stored for every word in the work process that the computer transcribed from speech into data. This took approximately 30-40 minutes to complete.

Once selectors finished setting up the voice template, trainers were assigned to accompany order selectors through their first voice selection assignment. Wearing a wireless receiver and headset, trainers could overhear selector and computer interactions. This allowed trainers to give order selectors quick feedback during training and allowed for the quick resolution of any issues. After the third or fourth assignment, that involved selecting 20 to 80 items, the order selector could continue the shift without assistance.

While the trainer worked with one selector, the remaining selectors in the department continued their usual selection assignments using handhelds.

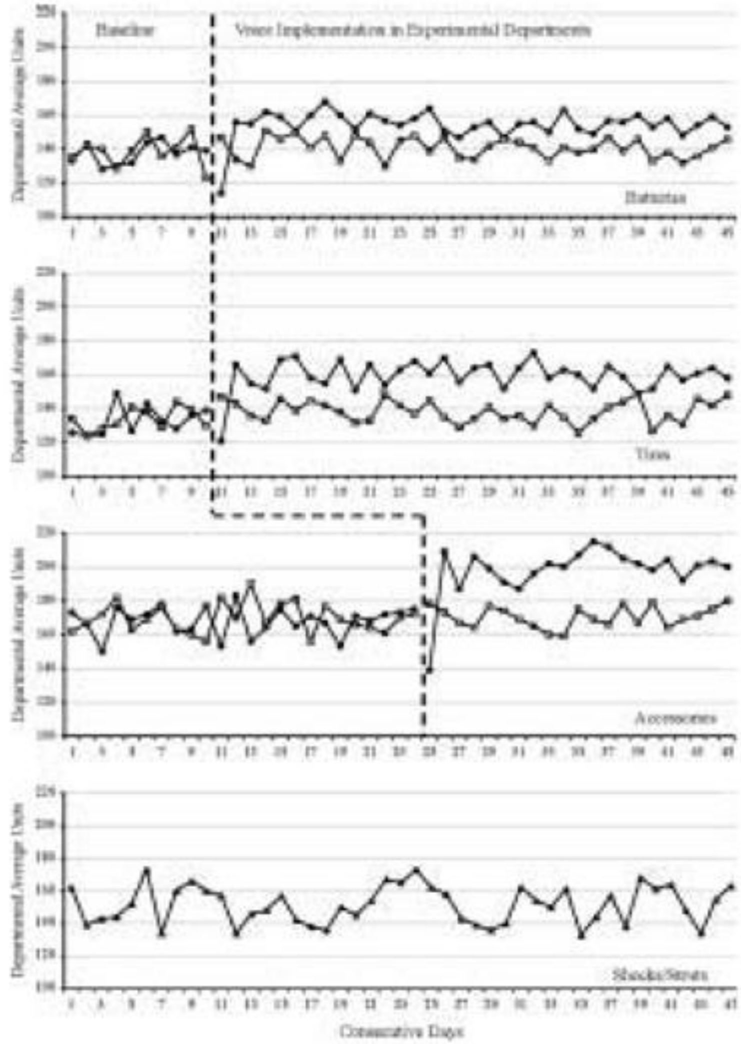
When voice training was completed for the first selector the next selector in the department was randomly selected for voice selection training. This process continued until all the selectors in the department were selecting via voice.

RESULTS

Productivity

The daily Departmental Average Units (DAU) for the experimental and comparison departments throughout the study are shown in Figure 6. Filled circles represent the data for the experimental departments that

FIGURE 6. Daily Departmental Average Units (DAU) for the Experimental and Comparison Departments Throughout the Study



Note: Filled circles represent the data for the experimental departments who switched from handheld technology to voice selection technology during the study. Open squares represent data for the comparison departments who used handheld computers throughout the study. Finally, triangles represent the data for the comparison department that used paper-based selection throughout the study.

switched from handheld technology to voice selection technology during the study. Open squares represent data for the comparison departments that used handheld computers throughout the study. Finally, triangles represent the data for the comparison department that used paper-based selection throughout the study. Additionally, Table 2

TABLE 2. Means and Standard Deviations for Departmental Average Units Across Departments and Phases

Department	Baseline Mean (*SD*)	Intervention Mean (*SD*)
Battery (Distr. Center A: Handheld to voice)	137.4 (6.44)	156.3 (4.66)
Tire (Distr. Center A: Handheld to voice)	133.0 (8.53)	160.8 (7.02)
Accessories (Distr. Center A: Handheld to voice)	169.0 (6.51)	200.8 (8.68)
Shocks & Struts (Distr. Center A: Paper only)	153.3 (12.85)	150.9 (11.38)
Battery (Distr. Center B: Handheld only)	138.6 (7.51)	140.9 (6.12)
Tire (Distr. Center B: Handheld only)	133.9 (6.56)	138.4 (6.39)
Accessories (Distr. Center B: Handheld only)	169.7 (8.77)	170.4 (6.27)

Note: Battery, tire, and shocks and struts comparison groups' baseline durations were calculated as using the baseline attributed to the battery and tire departments at Distribution Center A (i.e., handheld to voice). Accessories comparison group's baseline durations were calculated as using the baseline attributed to the accessory department at Distribution Center A (i.e., handheld to voice).

depicts the means and standard deviations for each department across experimental phases.

During the 10-day baseline phase for the Battery Department (N = 4) at the experimental distribution center, DAU was 137.4 and ranged from 128 to 147 (*SD* = 6.44). On the day of voice system training, the DAU dropped to 114. Departmental average units were 156.3 and ranged from 147 to 168 (*SD* = 4.66) during the rest of the voice system intervention phase. The difference between scan selection and voice selection DAU in Batteries, excluding data from the intervention day, was 18.9, an increase of 13.7%. The DAU for the Battery Department (N = 3) at the comparison distribution center, which used the handheld computer selection system throughout the study, was 140.90 and ranged from129 to 152 (*SD* = 7.50) over this same time period.

During the baseline phase for the Tire Department (N = 4) at the experimental distribution center, the average DAU for the Tire Department (N = 4) during baseline was 133 and ranged from 124 to 149 (*SD* = 8.53). On the day of voice system training, the DAU dropped to 121. The DAU was 160.8 and ranged from 151 to 171 (*SD* = 7.02) during the rest of the voice system intervention phase. Omitting the training day, the difference between scan selection and voice selection in Tires was 28 DAU, an increase of 21%. The DAU for Tire Department (N = 4) at the comparison distribution center, computer selection system throughout the study, averaged 137.22 and ranged from 124 to 148 (*SD* = 6.22) over this same time period.

During the baseline phase for the Accessory Department (N = 6) at the experimental distribution center, the DAU hour averaged 169 and ranged from 153 to 175 (*SD* = 6.51). On the day of voice system training, the DAU dropped to 139. DAU averaged 200.80 and ranged from 187 to 215 (*SD* = 8.68) during the rest of the voice system intervention phase. Omitting the training day, the difference between scan selection and voice selection in Accessories was 28 DAU, an increase of 19%. The DAU for the Accessory Department (N = 4) at the comparison distribution center, which used the handheld computer selection system throughout the study, DAU was 170 and ranged from 156 to 181 (*SD* = 6.72) over the same time period.

The DAU for the Paper (Shocks and Struts) Department (N = 7) was 151 and ranged from 134 to 173 (*SD* = 11.88) throughout the study.

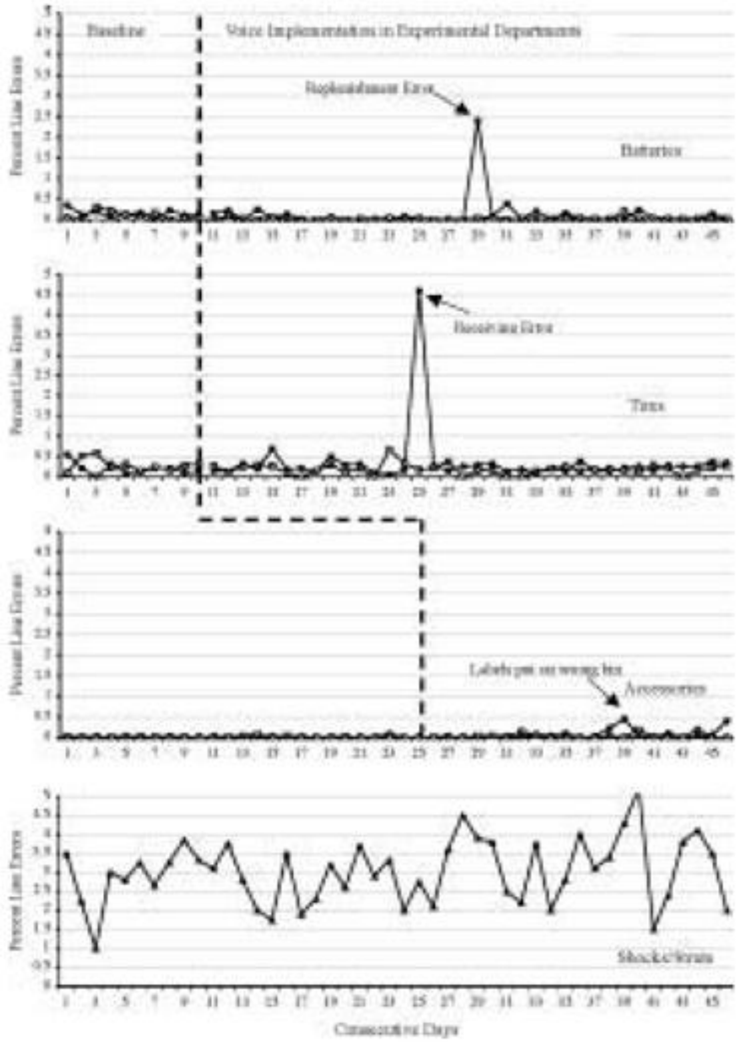
Accuracy

The Line Errors for the experimental and comparison departments throughout the study are depicted in Figure 7. Table 3 depicts the means and standard deviations for each department across experimental phases.

During the 10-day baseline phase for the Battery Department (N = 4) at the experimental distribution center, daily line errors averaged .15% and range from 0 to .34% (*SD* = .09). Line errors averaged .13% and ranged from 0 to 2.4% (*SD* = .40) during the rest of the voice system intervention phase. This represents a .02 ***percentage point*** decrease in line errors when the selection method was changed from handheld to voice technologies.

A greater percentage of line errors occurred on Day 25 in the experimental Battery Department. An investigation of warehouse data for that day revealed that batteries had been placed into an incorrect location by a fork-lift driver earlier in the day (a replenishment error, i.e., the wrong

FIGURE 7. Daily Percentage Line Errors for the Experimental and Comparison Departments Throughout the Study



Note: Filled circles represent the data for the experimental departments who switched from handheld technology to voice selection technology during the study. Open squares represent data for the comparison departments who used handheld computers throughout the study. Finally, triangles represent the data for the comparison department that used paper-based selection throughout the study.

product was used to refill a bin from which selectors selected items or products). When the selectors selected from the correct location they inadvertently selected the wrong batteries thereby causing the line errors.

Omitting Day 25, line errors averaged .06% during the voice system intervention phase. This represents a .08 ***percentage point*** decrease in line

TABLE 3. Means and Standard Deviations for Percent Line Errors Across Departments and Phases

Department	Baseline Mean (SD)	Intervention Mean (SD)
Battery (Distr. Center A: Handheld to voice)	.15% (.09)	.13% (.40)
Tire (Distr. Center A: Handheld to voice)	.20% (.15)	.35% (.74)
Accessories (Distr. Center A: Handheld to voice)	.02% (.02)	.08% (.13)
Shocks & Struts (Distr. Center A: paper only)	2.89% (.80)	3.06% (.89)
Battery (Distr. Center B: Handheld only)	.10% (.13)	.06% (.08)
Tire (Distr. Center B: Handheld only)	.28% (.15)	.18% (.13)
Accessories (Distr. Center B: Handheld only)	.02% (.01)	.04% (.06)

Note: Battery, tire, and shocks and struts comparison groups' baseline durations were calculated as using the baseline attributed to the battery and tire departments at Distribution Center A (i.e., handheld to voice). Accessories comparison group's baseline durations were calculated as using the baseline attributed to the accessory department at Distribution Center A (i.e., handheld to voice).

errors when the selection method was changed from handheld to voice technologies.

Daily line errors for the Battery Department (N = 3) at the comparison distribution center, which used the handheld computer selection system throughout the study, averaged .06% and ranged from 0% to .31% (*SD* = .04) over this same time period. Therefore, the average line errors for the comparison battery department using the handheld computers were nearly identical to the experimental battery department when they used voice selection.

During the 10-day baseline phase for the Tire Department (N = 4) at the experimental distribution center, daily line errors averaged .20% and ranged from 0 to .55% (*SD* = .15). Line errors averaged .35% and ranged from 0 to 4.6% (*SD* = .74) during the rest of the voice system intervention phase. This represents a .15% point increase in line errors when the selection method was changed from handheld to voice technologies.

A greater percentage of line errors occurred on Day 29 in the experimental Tire Department. An investigation of warehouse data for that day revealed that a fork-lift driver unloaded tires from the supplier's truck onto the wrong floor location earlier in the day. Omitting Day 29, line errors averaged .23% during the voice system intervention phase. This represents a .03% point increase in line errors when the selection method was changed from handheld to voice technologies.

Daily line errors for the Tire Department (N = 4) at the comparison distribution center, which used the handheld computer selection system throughout the study, averaged .20% and ranged from 0 to .67% (*SD* = .14) over this same time period. Therefore, the average line errors for the comparison tire department using the handheld computers were nearly identical to the experimental tire department when they used voice selection.

During the 25-day baseline phase for the Accessories Department (N = 6) at the experimental distribution center, daily line errors averaged .02% and ranged from 0 to .09% (*SD* = .02). Line errors averaged .08% and ranged from 0 to .45% (*SD* = .13) during the rest of the voice system intervention phase. This represents a .06% point increase in line errors when the selection method was changed from handheld to voice technologies.

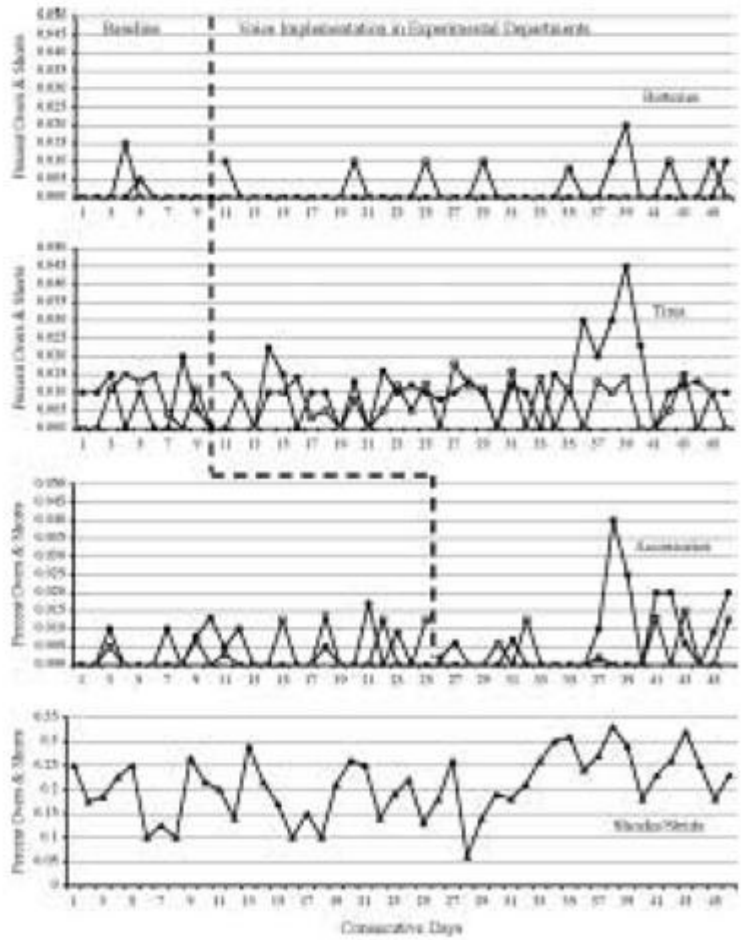
Daily percentage of line errors for the Accessories Department (N = 4) at the comparison distribution center, which used the handheld computer selection system throughout the study, averaged .03% and ranged from 0 to .20% (*SD* = .06) over this same time period. Therefore, the average line errors for the comparison accessory department using the handheld computers were fewer than the experimental accessory department when they used voice selection.

Daily line errors for the Shocks and Struts Department (N = 4) which used the paper selection system throughout the study, averaged 3.02% and ranged from 0 to 5.2% (*SD* = .87) over this same time period. Therefore, the average line errors for the comparison shocks and struts department using the paper selection was much greater than the departments that used the handheld and voice selection systems.

Overs and Shorts

The daily percentage of Overs and Shorts for the experimental and comparison departments throughout the study are depicted in Figure 8.

FIGURE 8. Daily Percentage Overs and Shorts for the Experimental and Comparison Departments Throughout the Study



Note: Filled circles represent the data for the experimental departments who switched from handheld technology to voice selection technology during the study. Open squares represent data for the comparison departments who used handheld computers throughout the study. Finally, triangles represent the data for the comparison department that used paper-based selection throughout the study.

Table 4 depicts the means and standard deviations for each department across experimental phases.

During the 10-day baseline phase for the Battery Department (N = 4) at the experimental distribution center, daily overs and shorts averaged .001% and ranged from 0% to .005% (*SD* = .002). Overs and shorts averaged .001% and ranged from 0% to .02% (*SD* = .004) during the rest

TABLE 4. Means and Standard Deviations for Percent Overs and Shorts Across Departments and Phases

Department	Baseline Mean *(SD)*	Intervention Mean *(SD)*
Battery (Distr. Center A: Handheld to voice)	.001% (.002)	.001% (.004)
Tire (Distr. Center A: Handheld to voice)	.007% (.007)	.012% (.01)
Accessories (Distr. Center A: Handheld to voice)	.003% (.005)	.008% (.01)
Shocks & Struts (Distr. Center A: Paper only)	.189% (.06)	.212% (.07)
Battery (Distr. Center B: Handheld only)	.002% (.005)	.002% (.004)
Tire (Distr. Center B: Handheld only)	.007% (.01)	.007% (.01)
Accessories (Distr. Center B: Handheld only)	.003% (.005)	.003% (.005)

Note: Battery, tire, and shocks and struts comparison groups' baseline durations were calculated as using the baseline attributed to the battery and tire departments at Distribution Center A (i.e., handheld to voice). Accessories comparison group's baseline durations were calculated as using the baseline attributed to the accessory department at Distribution Center A (i.e., handheld to voice).

of the voice system intervention phase. This represents no change in overs and shorts when the selection method was changed from handheld to voice technologies.

Daily overs and shorts for the Battery Department (N = 3) at the comparison distribution center, which used the handheld computer selection system throughout the study, averaged .002% and ranged from 0 to .015% (*SD* = .004) over this same time period. Therefore, the average overs and shorts for the comparison battery department using the handheld computers were nearly identical to the experimental battery department when they used voice selection.

During the 10-day baseline phase for the Tire Department (N = 4), daily overs and shorts averaged .007% and ranged from 0 to .02% (*SD* = .007). Overs and shorts averaged .012% and ranged from 0 to 05% (*SD* = .01) during the rest of the voice system intervention phase. This represents a .04% point increase in overs and shorts when the selection method was changed from handheld to voice technologies.

Daily overs and shorts for the Tire Department (N = 4) at the comparison distribution center, which used the handheld computer selection system throughout the study, averaged .007% and ranged from 0 to .018% (*SD* = .006) over this same time period. Therefore, the average overs and shorts for the comparison tire department using the handheld computers were nearly identical to the experimental tire department when they used voice selection.

During the 25-day baseline phase for the Accessories Department (N = 6) at the experimental distribution center, daily overs and shorts averaged .003% and ranged from 0 to .017% (*SD* = .005). Overs and shorts averaged .008% and ranged from 0 to .04% (*SD* = .01) during the rest of the voice system intervention phase. This represents a .005% point increase in overs and shorts when the selection method was changed from handheld to voice technologies.

Daily overs and shorts for the Accessories Department (N = 4) at the comparison distribution center, which used the handheld computer selection system throughout the study, averaged .003% and ranged from 0 to .015% (*SD* = .005) over this same time period. Therefore, the average overs and shorts for the comparison accessory department using the handheld computers were fewer than the experimental accessory department when they used voice selection.

Daily overs and shorts for the Shocks and Struts Department (N = 4) which used the paper selection system throughout the study, averaged .207% and ranged from .060 to .33% (*SD* = .065) over this same time period. Therefore, the average overs and shorts for the comparison shocks and struts department using the paper selection was much greater than the departments that used the handheld and voice selection systems.

DISCUSSION

Productivity

Organizations are continually concerned about increasing their own productivity in order to improve their operational effectiveness (Brethower, 2000; Sulzer-Azaroff, 2000; Mawhinney, 1992; Pritchard, Jones, Roth, Stuebing,&Ekeberg, 1988). This case study demonstrated that the evolution of technology can have a beneficial impact on productivity and quality. In an automotive aftermarket retailer's distribution center, voice technology implementation was associated with immediate and sustainable increases in productivity (i.e., DAU) in three key departments of the warehouse (i.e., batteries, tires, and accessories). Productivity increases were not observed in the same time frame among comparable departments of a comparison warehouse that continued use of handheld computer selection technology. These results were consistent with Miller's (2004) report on the use of selection technologies to improve warehouse productivity.

The increase in productivity (measured in DAUs) using voice selection versus handheld computer selection could have been owing to ergonomic factors. When selectors arrived at the product location they would have to draw their scanner from their holster, retrieve the product from the location, scan the product's UPC, enter the quantity selected, and then place the handheld back into the holster. This chain of events took an estimated 8-10 seconds to complete. When selectors began to use the voice system, they were able to maintain eye contact with the shelf location as they listened for product information. Selectors using voice technology only needed to state the check string orally for product verification thereby reducing the need for any further body movement. Voice technology eliminated this 8-10 second equipment handling time per selection which may have accounted for the increased DAU associated with the use of voice technology.

Additionally, the voice system interface made for more efficient input of information. When using the handheld selectors workers were required to key in the quantities, and additional information when mismatches occurred. Information input (quantities, mismatches, etc.), on the other hand, only required a couple extra verbalizations on the voice system. This difference between manual and verbal interfaces saved production time as well.

With voice selection, selectors may have been less likely to stop during their order runs to socialize with other workers because of the extra response cost of talking with the voice system in operation (Berger & Ludwig, 2007). Selectors would have had to command the voice system to deactivate to be able to talk to another person. They would then have had to reactivate the system orally. A reduction of on-the-clock socializing may also have contributed to increased productivity.

In the present study, the implementation of the voice technology was associated with an initial and substantial decrease in productivity for 1 day. This decrease was associated with the training of selectors on the voice system which slowed their pace as they worked with a trainer and discussed the new process. This temporary reduction in productivity associated with voice technology training lasted less than a single day reflecting a very steep learning curve for selectors to achieve higher levels of productivity.

Accuracy

Overall results demonstrated that the handheld and voice selection had significantly fewer errors than paper-based selection systems. When all three selection methodologies were compared, the lowest percentage of line errors was associated with the handheld selection system programmed to emit a second beep to indicate an error occurrence. Errors were the highest among selectors using the paper-based system. Similarly, the use of handheld technology was associated with lower errors than voice technology.

Voice selection line errors were higher on Day 25 in the tire department and day 29 in the battery department owing to incidents involving the wrong tires or batteries having been placed in the selection locations by fork-lift drivers during receiving and replenishment, respectively.

Not all line errors were attributed to receiving or replenishment errors. There were no receiving or replenishment errors that could account for nearly 1% error rate on Day 39 for Accessory selecting. Audit reports indicated that a product was selected from a location next to the correct location. Further investigation revealed that the labels for the two locations had been reversed. When labels were scratched or torn they were replaced and the associate responsible for replacing the labels affixed the two labels to the two locations in the reverse sequence compared to the correct sequence.

These results and subsequent investigation of spikes in the data suggest that line errors were higher for voice selection than handheld scanning owing to upstream events such as receiving, replenishment, or inventory control errors. This reveals certain vulnerabilities for voice selection. If an order selector was selecting from a location where the wrong product was placed in error, voice selection would not catch the error. With handheld order selection, on the other hand, upstream errors could be detected during the selection process because the order selector's UPC scanning activity would result in immediate feedback as a prompt regarding an impending wrong product selection.

Voice technology does permit selectors to query the computer for additional information, such as item description, to compare with the product's markings. However, this "checking" behavior may not be common. Future research regarding detailed performance-related behavioral effects of voice technology could address questions such as how employees might be trained to use the query feature in situations where the product to be selected appears to be incorrect.

We know from research reported here, however, that the old term GIGO is still valid, that is, garbage in garbage out. When the wrong task specifications are entered into a program (e.g., product location) the selector may make an incorrect selection due to the parameters fed into whatever device and its software used by the selector.

Study Limitations

These findings should be treated with a note of caution. In a field setting such as this one, gains in realism may often be offset by concerns for internal validity (Komaki & Goltz, 2001). Indeed, the current study could not randomly assign participating selectors to groups. Instead the researchers attempted to evaluate the impact of the voice implementation in a multiple baseline time-series format that provided comparison groups to contrast the different selection technology systems with selectors doing the same work (i.e., batteries, tires, and accessories) albeit at different warehouses. While the work processes, wages, incentive pay, and discipline systems across the warehouses were nearly identical, pre-existing differences between the intact departments (e.g., unique hiring practices, management styles, etc.) may have affected the results.

Additionally, the measures of productivity and accuracy may have been affected by slight differences across warehouses owing to the work volume (i.e., amount of items to be shipped) and warehouse layout. The differences in work volume across the warehouses may have been somewhat mitigated in that the dependent variables were calculated as a ratio that included volume. Performance was calculated as volume/hours and if there was not enough work volume to fill selectors' hours then they were taken off the line and their remaining time was not calculated in DAU. Additionally, errors were calculated using a sample of work that compared the number of errors to the volume of the sample. Therefore, it could be argued that differences in warehouse volume may not have resulted in different calculations of productivity and accuracy across the warehouses.

However, when a large volume of product is required to move through a warehouse, selection productivity may increase, but accuracy typically suffers. During periods of high volumes of order selection, managers may stress higher productivity and workers may see the need to speed up their work tempo to reduce the volume. In this case, actual productivity may increase under high volume. At the same time, when selectors are under more pressure to increase productivity they may take short cuts and/or move more quickly through their work process at the expense of committing more errors.

As noted already, Goomas and Ludwig (2007) reported on an implementation of employee work standards that compared employeeDAU's to a valid standard of production. In that report, differences in productivity and warehouse layout were factored into the standard which, in turn, factored out these influences in our measures. When using engineered labor standards, researchers can be more confident that the comparisons they have made among sites were indeed equivalent.

Implications

Organizational Behavior Management (OBM) can play a large role in adapting new technologies to maximize the effective, immediate, and personalized delivery of antecedents and consequences in order to increase productivity and accuracy in the workforce. Additionally, when behavioral contingencies are integrated into warehouse operations, such as through technology, there is a greater chance of the organization maintaining its use. Indeed, both handheld and voice technology deliver the enhanced contingencies efficiently and, according to this research, quite effectively.

Once these technologies are in place there are still further gains to be realized using OBM. Both handheld and voice technology software can be programmed to deliver other intervention operations through visual, auditory, or verbal communication. For example, a payment incentive plan could be adapted so that an employee could see how much additional incentive money had been earned (or lost) based on the performance level kept up to the minute on a handheld device. Voice could be programmed to interact with the warehouse management system to verbally tell selectors their daily cumulative performance level and the incentive money earned analogous to the Goomas and Ludwig (2007) study on handheld screens. Additional prompts, for performance or safety, could be delivered easily as well.

For researchers, these technologies also provide greater experimental control over their data collection process. Data are collected via a standardized and instrumented method thus reducing measurement errors typically associated with human observers. Additionally, intervention operations can be coded into software that could reliably deliver antecedent and consequent stimuli (task specifications and performance feedback) based on a specific schedule for each unit of work. The integrity of the independent variable is assured, if it has been subjected to tests for its reliability. Finally, interventions can be delivered to individuals privately through these technologies so many comparison groups can be randomly formed within the same work population.

Thus, the maturing field of human performance technology represents an excellent opportunity for OBM researchers (as well as researchers in other areas of psychology) to both enhance the efficacy of existing intervention methods and test theoretical constructs in a much more controlled environment.

REFERENCES

Alavosius, M.P. & Sulzer-Azaroff, B. (1986). The effects of performance feedback on the safety of client lifting and transfer. *Journal of Applied Behavior Analysis, 19*, 261-267.

Alvero, A., Bucklin, B., & Austin, J. (2001). An objective review of the effectiveness and essential characteristics of performance feedback in organizational settings (1985-1998). *Journal of Organizational Behavior Management, 21*(1), 3-30.

Balcazar, F., Hopkins, B.L.,&Suarez, Y. (1986).Acritical, objective review of performance feedback. *Journal of Organizational Behavior Management, 7*(3-4), 65-89.

Bateman, M.J. & Ludwig, T.D. (2003). Managing distribution quality through an adapted incentive program with tiered goals and feedback. *Journal of Organizational Behavior Management, 23*, 33-55.

Berger, S.M. & Ludwig, T.D. (2007). Reducing Warehouse Employee Errors Using Voice-Assisted Technology that Provided Immediate Feedback. *Journal of Organizational Behavior Management, 27*(1), 1-31.

Brethower, D.M. (2000). A systemic view of enterprise: Adding value to performance. *Journal of Organizational Behavior Management, 20*(3-4), 165-190.

Deming, W.E. (1982). *Quality, productivity, and competitive position*. Cambridge, MA: Center for Advanced Engineering Study, MIT.

Dihoff, R.E., Brosvic, G.M., Epstein, M.L., & Cook, M.J. (2004). Provision of feedback during preparation for academic testing: Learning is enhanced by immediate but not delayed feedback. *The Psychological Record, 54*, 207-231.

Epstein, M.L., Lazarus, A.D., Calvano, T.B., Matthews, K.A., Hendel, R.A., Epstein, B.B.,&Brosvic, G.M. (2002). Immediate feedback assessment technique promotes learning and corrects inaccurate first responses. *The Psychological Record, 52*, 187-201.

Gilbert, T.F. (1978). *Human Competence: Engineering Worthy Performance*. New York, NY: McGraw-Hill.

Goomas, D.T. & Ludwig, T.D. (2007). Enhancing incentive programs through proximal goals and immediate feedback: Engineered labor standards and technology enhancements in stocker replenishment. *Journal of Organizational Behavior Management, 27*(1), 33-68.

Hantula, D.A. (2000). Schedules of reinforcement in organizational performance, 1971-1994: Application, analysis, and synthesis. In C.M. Johnson, W.K. Redmon, & T.C. Mawhinney (Eds.), *Handbook of Organizational Performance: Behavior Analysis and Management*. Binghamton, NY: Haworth.

Hill, J.M. (1996). Warehouse management systems: The competitive tool for the 1990s. *Modern Materials Handling,* 51, 3-12.

Johnson, J. (2005, June). Sonic Boom, DC Velocity, Equipment and Applications, 3 (6), 1-3.

Jonassen, D.H., Tessmer, M., & Hannum, W.H. (1999). *Task Analysis Methods for Instructional Design*. Mahwah, NJ: Lawrence Erlbaum Associates.

Komaki, J.L. & Goltz, S.M. (2001). Within-group research designs: Going beyond program evaluation questions. In C.M. Johnson, W.K. Redmon,&T.C. Mawhinney (Eds.), *Handbook of Organizational Performance: Behavior Analysis and Management* (pp. 51-80). New York: The Haworth Press, Inc.

Lacefield, S. (2004, October). I can hear you now. *Logistics Management, Warehouse and DC section, 3*, 1-4.

Leivo, A.K. (2001). A field study of the effects of gradually terminated public feedback on housekeeping performance. *Journal of Applied Social Psychology, 31*, 1184-1203.

Luthans, F. & Kreitner, R. (1985). *Organizational Behaviour Modification and Beyond: An Operant and Social Learning Approach*. Glenview, IL: Scott, Foresman.

Malott, R.W. (1992). A theory of rule governed behavior and organizational behavior management. *Behavior Management, 2(2)*, 46-65.

Mason, M.A. & Redmon, W.K. (1992). Effects of immediate versus delayed feedback on error detection accuracy in a quality control situation. *Journal of Organizational Behavior Management, 13*, 49-78.

Mawhinney, T.C. (1992). Evolution of organizational cultures as selection by consequences: The Gaia hypothesis, metacontingencies, and organizational ecology. *Journal of Organizational Behavior Management, 12*(2), 1-26.

Miller, A. (2004). *Order Picking for the 21st Century*. Unpublished white paper: Tompkins Associates, Raleigh, NC.

Parks, L. (2004, July 5). Voicing approval. *Supermarket News: Retail Systems/Supply Chain* section*, 52*(27), 1-3.

Poling, A. & Braatz, D. (2000). Principles of learning: Respondent and operant conditioning and human behavior. In C.M. Johnson, W.K. Redmon, & T.C. Mawhinney (Eds.), *Handbook of Organizational Performance: Behavior Analysis and Management*. Binghamton, NY: Haworth Press, Inc.

Sink, D.S. & Tuttle, T.C. (1989). *Planning and Measurement in Your Organization of the Future*. Norcross, GA: IE Press.

Sulzer-Azaroff, B. (2000). Of eagles and worms: Changing behavior in a complex world. *Journal of Organizational Behavior Management, 20*(3-4), 139-163.

Sulzer-Azaroff, B. & Mayer, G.R. (1991). *Behavior Analysis for Lasting Change*. Fort Worth, TX: Harcout Brace College.

Wulfraat, M. (May, 2002). *Voice Technology in the Distribution Center*. Unpublished white paper: KOM International.