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Ergonomics Improvement in a Dairy Manufacturing Plant Comparing a Voice Feedback System That Replaced a Wireless Handheld System

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Abstract

The study reports on improved order selection ergonomics, feedback delivery, productivity, and worker satisfaction by replacing a wireless handheld device system with a voice feedback system. 'Order selectors' at a dairy manufacturing plant are tasked with selecting dairy products for store orders (e.g. grocery stores, convenience stores). In the new voice feedback system, workers listened to instructions via a headset and spoke directly into a microphone, receiving immediate voice feedback. The voice system was instrumental in increasing the productivity of order selection tasks where baseline order completion that averaged 35.6 minutes per order via wireless handheld devices was reduced by 23%. Work satisfaction increased due to eliminating hand motions used in the wireless handheld system (holstering and un-holstering the unit) and having to enter data while wearing gloves. This study suggests that industrial settings with similar settings and workflows can be aided with a voice feedback system, costing less than wireless handheld systems and with appreciably higher ergonomic, productivity benefits, and worker satisfaction.

Keywords: Dairy manufacturing plant; wireless handheld order selection; immediate voice feedback; voice technology

Introduction

Feedback in the workplace is instrumental in affecting workers' performance by motivating them to adjust their work output, reinforcing their response pattern and directing them towards a performance goal. Most definitions of feedback specify that it is information received by a responder regarding their performance on a task or set of tasks. Shikdar and Das [11] studied the manner by which production standards or goals and performance feedback affected the relationship between worker satisfaction and productivity. Gramopadhye and Wilson [9] studied the effect of feedback training of output errors on inspection performance. Field studies by Yeow and Sen [13,14] showed that clearer feedback, e.g. pass/fail criteria, and clearer component marking improved operators' performance (in terms of productivity and quality) at an electronics manufacturing company. Alder [1] examined the relationship between feedback and performancein a monitored environment and found that feedback enhanced operators' desire to improve, which was related to performance. In Alvero et al.'s [2] review of feedback literature, it was found that between different combinations of feedback and feedback delivery, the results of feedback were most robust when paired with antecedents and consequences. The present study aims to investigate the ergonomics of using a voice feedback system that replaced a wireless handheld system regarding delivery of feedback, productivity, quality, cost effectiveness, and operators' satisfaction as the ergonomics measurements.

Work environment and operator's task at a dairy manufacturing plant

Workers at the host company dairy manufacturing plant work inside an environment set at about 7° Celsius. The workers' environment can often be harsh and loud, whether a worker is working on a filler line, unloading trucks from a supplier, selecting orders, or loading trucks for store orders. Working in this refrigerated environment requires the worker to wear protective clothing. In addition to wearing overcoats and non-slip shoes, the worker has to carefully navigate slippery floors due to multiple wash-downs throughout the day (see Figure 1). Additionally, there are increased noise levels and wind due to large overhead blowers and fans.

Figure 1: Multiple floor wash-downs each day within this dairy manufacturing plant create slippery conditions both for the machine operators and order selectors.

Each store order that is received by the host company dairy manufacturing plant is converted into a selection guide. The task of an 'order selector' is to select products for these store orders. They travel by handcart, pallet jack, or forklift to various rack, bin, or floor storage locations selecting products in accordance with an selection guide. Once the selection guide is completed, the order is delivered to an outbound truck (or staging lane) for transport to the store for delivery.

Wireless handheld devices

At the host company, the technology for order selectors to process store order electronic selection guides occurred with a wireless handheld device (Figure 2, right panel). The computer screen depicted key information for each product that a store ordered: the storage location of the product within the warehouse, the product description, and the quantity to pick. The workflow was as follows:

1) Order Selector (user) walks to the shipping office to get a wireless handheld device from the battery charger station. The user also obtains a holster and fastens the holster to his waist (the holster is used to place the wireless device into the holster while the worker is using both hands to select products within the store order).
2) User signs into the wireless handheld device (Figure 2, right panel).
3) Work is transmitted from the Warehouse Management System (WMS) to the user's handheld device.
4) User obtains two to 3 empty plastic totes for product placement to fulfill store orders.
5) User views the screen display for the first/next product description (e.g., 'one percent chocolate pint') of a store order.
6) User walks with a pallet jack (or hand truck) to the storage location where the specified product is stored
7) User grasps and raises the specified product from a case (see Figure 2, left panel).
8) User aligns the handheld scanner with the product's bar-coded UPC (Universal Product Code)
9) User squeezes the trigger on the handle of the device in order to activate the laser sensor. The user listens for beeps:
■ No beep? (did not scan the bar-coded Universal Product Code) - go to Step 8
■ One beep? – product scanned is the product associated with the store order
■ Two beeps? – product scanned (1st beep) is not a product associated with the store order (1/2 second delay, followed by a 2nd louder beep)
■ Go to Step 5
10) User replaces the product back into the case.
11) User enters the number of units of the ordered product (see Figure 2, right panel).
12) User presses the 'enter' key on the keypad to update the inventory of the WMS
13) User holsters the device
14) User selects the number of units and places these units into a plastic tote
15) User retrieves the device from the holster and views the screen
16) Is there another product in the store order?
a. Yes – go to Step 5
b. No – The user transports the tote(s) to a waiting truck (or a staging lane)
17) Are there more orders?
a. Yes – Go to Step 3
b. No – the user logs off and returns equipment to the battery charging station

Figure 2: The order selector lifts the product in order to scan the barcoded UPC of the product (left panel). This product validity check is to confirm the product is part of the store order. Once the UPC scan is successfully completed, the user enters the number of units of the ordered product (right panel) and then holsters (left panel, red square) the device in order to select the units onto the pallet (or tote). In the right panel, the user is wearing gloves while pressing the keys on the wireless handheld device.

Voice System – 'hands-free' and 'eyes-free'

Processing store order selection guides were presented electronically via voice feedback system. The voice-directed application is a wireless, wearable system that allows employees to perform their job functions "hands-free and eyes-free" [3, 10]. The hardware includes a battery-powered waist unit and a wireless battery-powered headset with an attached microphone that connects via wireless to a WMS (Figure 3). The workflow was as follows:

1) Order selector (user) obtains a voice unit with a headset unit from the battery charger station located in the shipping office.
2) User signs in to the voice system
3) Work is transmitted from the WMS to the user's device.
4) User obtains two to 3 empty plastic totes for product placement to fulfill store orders.
5) System states 'ready to start'
6) User says 'ready'
7) System states the first/next product description of a store order (e.g., 'one percent chocolate pint')
8) User walks with a pallet jack (or hand truck) to the storage location where the specified product is stored
9) User speaks into the microphone the specified product (e.g., 'one percent chocolate pint')
10) Does the stated product match the product heard over the headset?
• No – system repeats the product description in case the user is standing at the wrong location; workflow returns to Step 8
11) System states 'pick n' (n= number of units), for example 'pick 10'
12) User selects the number of units and places these units into a plastic tote
13) User says 'n' (in the example of 10 units, the user says 'one zero')
• Inventory of the WMS is updated
14) Is there another product in the store order?
a. Yes - Go to Step 7

b. No – the user transports the tote(s) to a waiting truck (or a staging lane)
15) Are there more orders?
a. Yes- Go to Step 3
b. No – user says 'log off' and returns equipment to the battery charging station

At no time does the order selector have to divert their eyes (eyes-free) from the selected product in order to scan the UPC as is done with the wireless handheld system. There is no equipment to holster and un-holster ('hands-free') and there is no data entry to perform. The product validity check was quite different between the two systems. In order to ensure the order selector was selecting from the correct storage location, the wireless handheld system used a series of beeps (Step #9 of the wireless handheld device workflow). Whereas with the voice system, the order selector hears the product stated (Step #7 of the voice device workflow).

Figure 3: A worker wearing a voice unit in a distribution center placing products (brochures and pamphlets) into a train of totes (left panel); a worker in protective clothing working, order selecting in a frozen distribution center. It should be noted that the headset and the microphone worn by both workers are both wireless.

Study Objective

There are few field studies on the effectiveness of order selection ergonomic systems in large industrial settings, such as distribution centers, warehouses, and manufacturing plants. Studies by Goomas [6] and Yeow and Goomas [12] have reported on an ergonomics intervention using a wireless handheld scanning system that replaced a paper system to process store orders. These studies compared a conventional paper order pick list with an ergonomic improvement using wireless handheld devices where the results showed productivity improvements and order selection errors were significantly reduced. Whereas these studies reported on replacing a paper system with a wireless handheld system, this field study is different in that it examined the adaptation and ergonomic/effectiveness of replacing a wireless handheld system with a voice feedback system.

A second objective of this field study was to report on worker satisfaction with the new voice technology. Earlier studies by Ludwig and Goomas [10] and Berger and Ludwig [3] did not address the ergonomics aspects, for example, operators' satisfaction of the voice system and how the system affected their task in consideration of the work environment. This study addressed worker satisfaction by conducting interviews and an assessment utilizing a questionnaire survey of the new technology.

Method

Participants: The field study occurred at a refrigerated dairy manufacturing plant located in a Rocky Mountain state. The order selectors were all male (N=5). Their ages ranged from 22 to 32 years (mean 24.6 years), and all order selectors had worked at the facility from ½ year to 3 years. All order selectors worked 8 ½ hour days Monday through Friday, beginning at 8:00 a.m. The company provided two 15-minute paid breaks and a 30-minute lunch. There was no turnover among the order selectors at this facility during the study. The size of the dairy plant was approximately 85,000 sq. feet.

Task: Products that were selected for store orders included pint drinks (e.g., white, chocolate, strawberry milk, teas, and citrus drinks), 6-oz yogurt cups, yogurts drinks, dairy creamers, aerosol whipping cream, and dips, to name a few. Products were selected from storage locations and placed into plastic totes to fulfill store orders. The order selector picked up two to 3 empty plastic totes from the tote pool and placed the totes onto a handcart as he traveled from one aisle to the next, from one storage location to the next location within each aisle, placing products into the totes in order to fulfill a store order. When the order selector finished selecting the store order, the selector transported the totes to a waiting truck or to a staging lane (Figure 4).

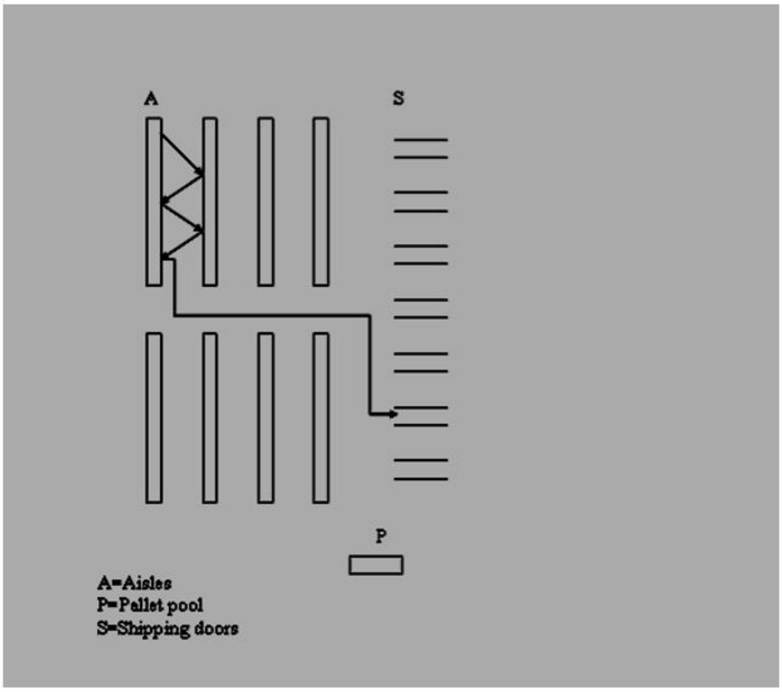

Figure 4: A diagram of the warehouse where products are selected from many storage locations within each aisle (A); once the order is finished, it is then transported to a shipping door (S). Each order begins with a selector obtaining a pallet (P) or totes from the pallet (or tote) pool

Research Design

The study used a pre-and post-test within-group design. There was a six-week baseline for the wireless handheld system followed by ten weeks with the new voice delivery system for store orders. Order selection tracking lasted a total of 80 days (16 weeks x 5 days).

Productivity and Worker Satisfaction

One dependent variable was the productivity of the order selector as measured by the Aggregate Selection Cycle Time (ASCT) to select a store order. The selection cycle time was calculated for each product selected by calculating the aggregate cycle times (start time and end time) between the wireless handheld system for steps 1 through 17, and the voice system for steps 1 through 15.

The researcher collected start and completion data for six store orders per day for each of the five selectors. Data was collected for two store orders at the start of the shift, one store order before lunchtime, one store order after lunchtime, and two orders at the end of the shift. Taking multiple timings, such as at the beginning, middle, and end of a shift, ensured that the orders were representative and that allowances for such factors as fatigue and travel time were taken into account [7].

In general, each store order ranged from about 30 to fifty products. ASCT does not include travel time to go to the empty tote pool and pick up empty totes, the time to shrink-wrap the tote(s), and the time to transport the shrink-wrapped tote(s) out to the waiting truck (or a staging lane).

For the second dependent variable, employees' satisfaction was measured through a) unstructured interviews [12], and b) an employee satisfaction survey. For the unstructured interviews, the experimenter sat with the order selectors in the break room at their designated break time throughout the first week of the intervention. These informal settings offer valuable feedback and opportunities to determine whether they were satisfied with the new voice system. All five order selectors were asked to provide feedback on how they felt about the new voice system compared to the previous wireless handheld device system. Each worker was interviewed separately to avoid bias influencing the opinions of the others. The employee satisfaction survey was conducted one week after the implementation of the voice system using the questionnaire in Table 1. The employee satisfaction survey was administered individually to all five order selectors.

Adaptation and Implementation of the Voice System

Shift meetings took place on days 28 and 29 into week 6 of the baseline announcing the date from the transition from the wireless handheld system to the voice system, informing the order selectors of the new technology. On these days, the trainer gave a demonstration of the voice unit device and a headset explaining the new technology and the benefits associated with the voice technology. Each order selector was given about a 10 to fifteen-minute training session on the new voice system. These meetings clearly stated that on the day of the implementation, all order selectors would begin the order selection process using the new voice system.

On the day of implementation, the trainer accompanied the order selectors into the refrigerated facility and worked with them throughout the first week of voice implementation. The trainer wore a wireless receiver and headset, allowing the trainer to follow each order selector and listen to speech and computer interactions. This allowed the trainer to provide quick verbal feedback and quickly resolve any issues as needed.

Results

Aggregate Selection Cycle Time: Figure 5 shows ASCT for the 16-week study, consisting of a 6-week wireless handheld system baseline and a 10-week voice implementation. As there were six orders tracked per selector per day, there were 150 tracked orders per week (6 orders per day x 5 selectors x 5-day work-week), for a total of 900 orders that were tracked via the handheld device (150 orders per week x 6-week baseline). There were a total of 1,500 orders tracked via the voice system (150 orders per week x 10-week implementation).

The ASCT for the wireless handheld devices averaged 89 hours per week and ranged from 86 to 95 hours (SD=4.05). Based on 535 total ASCT hours spanning the 6-week baseline divided by the 900 orders tracked, the average time to complete a store order was 35.6 minutes:

- 35.6 = (535 hours * 60 minutes) / 900 orders

Starting with the implementation of the voice system on Week 7 (minus the first day of implementation), the ASCT averaged 68 hours per week and ranged from 62 to 73 hours (SD = 4.04). Based on 681 total ASCT hours spanning the 10-week implementation divided by 1,500 orders tracked, the average time to complete a store order was 27.2 minutes:

• 27.2 = (681 hours * 60 minutes) / 1,500 orders

A 23% reduction in ASCT from when the wireless handheld system was gained by the voice system, primarily due to eliminating wireless handheld steps 5, 7 through 13, and 15, altogether, where the device is holstered, un-holstered, and the operators pressing keys to enter data. Comparing the wireless handheld system with the voice system, the value of Cohen's [4] *d,* which measures the standardized difference between two homogeneous means computed to 4.91 with an effect size *r* of 0.92. This suggests that the voice system intervention successfully reduced the elapsed time for order selectors to select store orders.

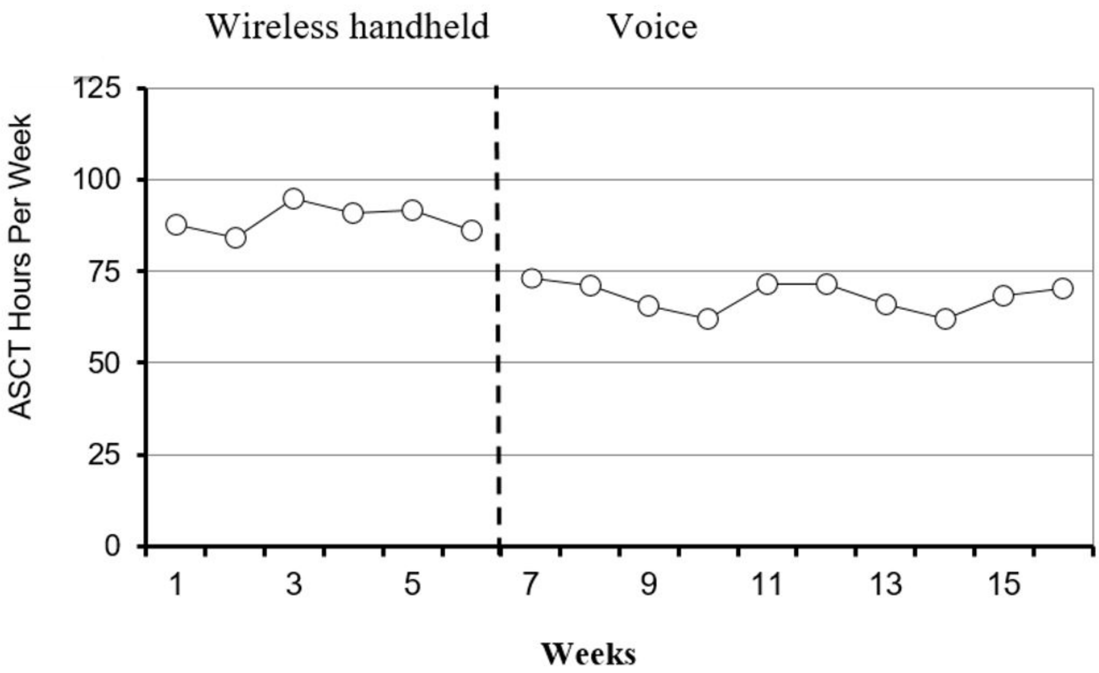

Figure 5: Aggregate Selection Cycle Time (ASCT) comparing wireless handheld device performance with voice performance. Each open circle represents an aggregate of 150 orders per week (5 selectors x 6 orders, picked at various times throughout the shift x 5-day work-week)

Unstructured interviews and employee satisfaction survey

In the unstructured interviews which took place in the break room when the order selectors were on break, all five order selectors' feedback reported how the new system had improved the order selection process, compared to the wireless handheld system. All five workers reported that voice technology eliminated the holstering and un-holstering and entering data that was required with the wireless handheld device. "Hands-free" allowed the workers to focus more on the hazards of wet floors in their travel path. None of the order selectors wanted to return to the wireless handheld device system.

The results of the employee satisfaction survey are presented in Table 1. The five order selectors reported on the benefits subsequently to implementing the new voice system for the following reasons:

(1) It made their job easier with their hands-free from having to holster and un-holster the wireless handheld device, look at the screen, enter data, and listening for beeps.
(2) It made their job safer because they could focus on looking ahead for any slippery floors (Figure 1).

Question		
1) Which method do you prefer?	Handheld (0)	Voice (5)
2) I am open to new technology - agree or disagree	Agree (5)	Disagree (0)
3) Which technology allows you to be safer?	Handheld (0)	Voice (5)
5) Did the company provide you with adequate training to learn the voice system?	Yes (5)	No (0)
6) Which technology allows you to stay focused?	Handheld (0)	Voice (5)
7) Would you ever return to handheld?	Yes (0)	No (5)
8) I feel voice made my job easier- agree or disagree?	Agree (5)	Disagree (0)

Table 1: The employee satisfaction survey was administered to the five order selectors of the voice system one month after the new voice device technology (number of responses in parentheses)

Discussion

Productivity, ergonomic improvement, and feedback delivery

These findings are consistent with other studies that discovered similar productivity improvements when a voice feedback system was used in an auto-parts distribution center [10] at a grocery distribution center [3] and at an ice cream manufacturing plant [8]. Using voice system eliminates multiple occurrences of holstering and un-holstering the device for each product using a handheld system or shuffling and sorting paper pick lists in a paper system.

Throughout an 8-hour shift, an order selector might handle, holster, and un-holster the handheld unit from 300 to 700 times. Additionally, the order selector has to listen for beeps (Step #9 of the wireless handheld device workflow). Once the product is confirmed as part of the store order, the order selector has to key in the quantity selected (Step #11 of the wireless handheld workflow) for each product that is part of the electronic selector guide. Comparing workflows, steps 5. 7 through 13, and 15 of the wireless handheld system workflow were eliminated with the voice system.

Upon implementing the new voice system, the workflow for the order selectors in the refrigerated setting changed substantially. Before the voice implementation, users had to scan a UPC, listen for beeps, holster and un-holster the wireless handheld device, and enter data onto a computer screen (see Figure 2). After the implementation, all WMS communications were done by listening on the headset and speaking into the microphone. While wearing gloves, the order selector had difficulty pressing small buttons on the handheld devices (Figure 2). With the voice system, workers were better able to focus on selecting product and navigating slippery floors without the distraction of the handheld device.

There are significant differences in delivery of feedback between the two systems. Whereas the wireless handheld system relied on the user to listen for beeps (no beep meant no proper scan of the UPC; one beep meant the scan of UPC was successful and the product was part of the store order; two beeps, separated by ½ second, meant the scan of the UPC was successful but the product scanned was not part of the store order). In contrast, the feedback of the voice system was heard through the headset in that the system repeated the product description if the product description said by the operator did not match the store ordered product. In either case, the double-beep or the product description that was repeated, generally meant the operator was about to select an incorrect product for the store order, thus eliminating a selection error.

Cost effectiveness

For an ergonomic improvement to be cost-effective, it has to be affordable to the industry. Ergonomics interventions may never be implemented if top management cannot justify the financial benefits of implementing, in this case, a voice system. This study will give managers a stronger justification to implement a voice system, given the return on investment and the workers' satisfaction reported here. When it comes to order selection, the suitability of the voice system is cost-effective when compared to handheld units. The cost of a "ruggedized" handheld unit designed for harsh environments can be approximately 3 to five times more expensive than a voice unit.

Limitations of the study

In real-life studies, there may often be a limited number of participants – in this case, the study was done with five order selectors. Furthermore, the research did not include reversals. To perform a reversal, the voice equipment would have to be removed, and the wireless handheld devices would have to be reinstated. And, of course, returning to the voice system at some later date. When comparing the performance improvements of the voice system, there is much resistance to the reversal of positive effects, as noted by Gaetani, Hoxeng, and Austin [5].

Conclusion

This field study reported on ergonomic improvement and worker satisfaction when using a voice-directed system in a refrigerated environment at a dairy manufacturing plant. The voice system was found to be more ergonomic than a wireless handheld system regarding 'hands-free' and 'eyes-free' in a harsh environment, and its cost-effectiveness, all key contributions of this study. Furthermore, the voice feedback system was a much safer approach in that the operator's eyes could focus on navigating the wet floors of the dairy manufacturing plant. The voice feedback system was found to be a more ergonomic system compared to the wireless handheld system considering performance feedback, hands free, harsh environment, and cost effectiveness. This finding is unique and is the key contribution of the research.

This field study should aid to management in deciding to use a voice system in facilities where workers work in a harsh environment where they perform order selection tasks. Other facilities where such an implementation would be beneficial would include refrigerated facilities that warehouse fish and meat products. By implementing a voice system that replaced a wireless handheld system, this study demonstrated ergonomic improvement to the satisfaction of the targeted population.

Declaration of Competing Interest

Funding and/or Conflicts of interests/Competing interests

The author did not receive support from any organization for the submitted work.

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