Chapter X

REDUCING HUMAN ERROR IN THE QUALITY CONTROL CHECKING OF FRESH PRODUCE LABELS

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ABSTRACT

Human error in the quality control checking of fresh produce labels results in financial loss, reputational damage, and a significant carbon footprint. This chapter reviews a research project aimed at understanding the reasons for such human error. In the course of the project, observations were taken in a packaging facility, historical error records were studied, key operatives were interviewed, and laboratory-based work was conducted. The in-situ observations highlighted the dynamic environment in which label-checking took place. The interviews revealed that no explicit training was given in label-checking. Respondents also identified a range of cognitive and situational factors likely to contribute to increased human error. Laboratory-based work, using an eye tracker to record eye movements during simulated label-checking tasks, showed that varying strategies were adopted by different quality control professionals. A systematic approach, in which one bit of information was checked at a time, was associated with more accurate performance. Several cognitive abilities were found to predict accurate label-checking performance in both quality control professionals and university students. Implications for personnel selection, training, human performance, and task design are identified. The understanding of human quality control checking gained from this project can be used to reduce human error and, thus, waste across different manufacturing domains.

INTRODUCTION

Human error in the quality control checking of the labels which accompany packaged fresh produce has been estimated to cost the UK supermarket industry millions of pounds per year in fines, product recall, repackaging, and replacement (S. Hinks, Product Technical Manager: Fruit and Floral, Sainsbury's Supermarkets Ltd, personal communication, July 2012). Despite the financial, reputational, and environmental costs attached to this reducible if not avoidable waste, human error in the quality control checking has been underexplored area of applied research. The current chapter reviews a research program that was carried out in order to understand the reasons for human error in the quality control checking of the labels which accompany packaged fresh produce and to identify the ways in which performance could be improved. There is a pressing need for such research not just in the UK food industry but wherever similar forms of quality control take place.

In the course of this research program, a range of studies were carried out [1,2,3,4]. These employed different methodologies in order to gain a greater understanding of the factors that contribute to human error in quality control label-checking. As a first step, an understanding of the label-checking process was acquired through in situ observations and interviews with the key personnel involved in label-checking. Further to this, the historical error data held by the packaging company were consulted to provide insights into the type of errors that occurred and how these mapped on to shift patterns and times of day. Following this initial work, the research program moved to the laboratory setting, with label-checking behavior being studied under carefully controlled conditions; firstly, to determine whether there was an optimal approach to label-checking and, secondly, to see the extent to which the accuracy of label-checking performance could be predicted on the basis of cognitive abilities and other characteristics.

THE PROCESS OF PACKAGING FRESH PRODUCE

The company's commercial office receives updates on a weekly basis from the commercial teams of a number of supermarket chains, setting out size changes, promotions, et cetera for the fresh products that they require. Members of the commercial office enter the updates into a product specification sheet. The product specification sheet contains the details of the supermarket orders for processing by the pack-house, with one line of the spreadsheet reflecting one packaging run. For each entry on the product specification sheet, between three and 11 fields of information are displayed (such as the name of the product, its country of origin, its best-before date, and the quantity or weight of the required product). Figure 1 shows a simplified example of a product specification sheet, as used in the experimental work described in this chapter. As is the case with the product specification sheets used in the pack-house, some items have current promotional offers on them, while others do not. The information so entered into the product specification sheet is then checked by two members of staff in the commercial office against the details set out in the email or telephone communication from the supermarket.

PRODUCT	COUNTRY	GROWER	QUANTITY	BB	BARCODE	Promotion Ribbon / Label
WHITE FLESH NECTARINES	FRUITS-SAL, SOUTH AFRICA	SILVER FIRE	X 4 FRUIT	02-Dec	0168 9341	MIX & MATCH Any 2 for £4
YELLOW FLESH NECTARINES	FRUITS-SAL, SOUTH AFRICA	CRIMSON GIO	X 4 FRUIT	01-Dec	0158 5049	MIX & MATCH Any 2 for £2.50
YELLOW FLESH NECTARINES	CAPE-REM, SOUTH AFRICA	MAYGLO	X 4 FRUIT	02-Dec	0158 5049	
STRINGLESS BEANS	MOROCCO	LARA CASTANDA	225G	04-Dec	0103 9429	
STRINGLESS BEANS	HOLLAND	VALSTAR	225g	03-Dec	0103 9429	Half price

Figure 1. An example of a simplified product specification sheet.

Once it has been checked by the commercial office, the product specification sheet is sent to packaging line leaders and label print room staff in the pack-house. The information that it provides is used by the pack-house to make up the orders for shipping across the entire supermarket chain over the course of that week. Further updates to the current product specification sheet are made if necessary. At the end of the week, a new product specification sheet is produced.

In the pack-house, the packaging line leader leads a team of operatives working on a particular packaging line. It is their task to process the orders specified on the product specification sheet. The packaging line leader initiates the process by generating a label check sheet. He or she then checks this check sheet against the size or quantity of the fresh produce being received and the list of growers and varieties approved by the supermarket in question. Following this, the specified quantities or weights of loose fresh produce are transported from warehouse storage to be packaged according to the requirements set out in the product specification sheet (e.g., four apples per pack, 250g of grapes per punnet). The type of packaging required varies depending on the type of fresh produce, such that the contents may be packed in punnets with a sealed label, netted or sealed in polythene packets.

The printing of labels to accompany the packaged fresh produce is an integral part of the packaging process. The line leader orders the required number of labels from the print room, where staff receive the orders and print the labels (except where fresh produce packets are sealed in film, where dedicated printing machines form a part of the packaging line itself). The line leader then collects the labels and distributes them to his or her team for appending to each unit that is packaged. Depending on the product, the number of fields of information presented on the product label varies but the details presented on it should match those set out on the product specification sheet. In addition, a further ribbon or sticker may be required to accompany the label. Known as a "flash label", this label highlights any current promotional activity on the product (for example, "Buy one, get one free"). An example of a product label is shown in Figure 2, together with an accompanying flash label (in this case, "Mix & Match. Any 2 for £2").

Figure 2. An example of a fresh produce label with an accompanying flash label.

While errors can originate in other parts of the company (e.g., the sales department, where orders are taken from various supermarket chains), the focus of the research program was on those arising in the pack-house, which was identified by the company's management as being the main source of error. Different packaging technologies had been introduced at different times on different packaging lines in order to meet the demands of packaging fresh produce in different ways (such as single items, e.g., melons, and those packaged in punnets, e.g., berries and grapes)). Given the resultant complexity of the production lines, the company's management did not deem an overarching software solution to the problem to be possible. The quality control process, therefore, is in place to ensure that the information which is displayed on the product packaging matches exactly with the contents of the packaging itself, both in terms of product characteristics and current promotional offers on the product. The task of checking labels involves two main sources of information – the product label and the product specification sheet – in addition to a visual check of the product itself (e.g., to ensure that four apples are indeed contained in the packaging as indicated on the product label). In carrying out a quality control check, the operative must cross-check each of the fields on the fresh produce label against their corresponding entries on the product specification sheet.

It was observed there was a constant flow of labels to be checked throughout the day. Observations of label-checking on the pack-house floor indicated that it took quality control staff 20s on average to complete a label check. The results of the check are recorded on a checklist which has to be signed off by the label-checker. Three or four such label checks are conducted by different operatives before the fresh produce leaves the packaging facility.

INSIGHTS FROM HISTORICAL ERROR DATA AND INTERVIEWS WITH KEY LABEL-CHECKING OPERATIVES

The vast majority of errors are detected early in the packaging process but there are very considerable costs attached to those label errors which escape detection, both in terms of monetary fines and/or the recall and replacement of otherwise perfectly good fresh produce from supermarket shelves. By way of example, in the month of March 2014, less than 1% of orders contained label errors and, of this 1%, only 5% went undetected during quality control checking.

There are two day shifts and one night shift in the pack-house, with the latter having fewer operatives and fewer packaging lines running. The average shift length was 9.5 hours, including breaks. When the historical error data were examined, more errors were recorded as having occurred during the day shifts (particularly in the morning, between 06:00 and 10:30, and especially so either side of their morning break at 09:00). This increased recorded frequency coincided with the point in the day when quality control staff identified themselves as being at their busiest. Only 15% of errors occurred in the afternoon shift. Fewer lines, typically three, run during the night shift (18:00-06:00) and few errors were recorded as having occurred during this shift. The most frequently recorded errors involved packaging (rather than labelling) errors, involving promotional offers and the wrong stop/start dates for these offers. Spelling errors were also a frequent source of error (e.g., misspelling the name of the grower of the fresh produce or typing “friut" instead of “fruit” since there was no spellchecking facility on the system to detect and correct such errors automatically).

In addition to studying the historical error data held by the packaging facility, structured interviews were conducted with key pack-house staff involved in the label checking process [3]. Three or four errors were estimated to occur in the pack-house per day but the interviewees reported that most of these errors were not recorded since they had been corrected at the time of being noticed. Uncorrected mistakes can be very costly. For example, a packaging error on an order of raspberries was reported as requiring 15 people to work for three hours to repackage 400 punnets of raspberries. Over 60% of the quality control staff interviewed identified the following key contributing factors to label-checking error: feeling unwell, a high workload, a small point size being used in the printed information appearing on either the label or the product specification sheet, more fields of information being presented on labels, and high noise levels occurring in the pack-house environment.

The interviews also revealed that the staff had not received any explicit instruction or training in the task of label-checking, mainly due to there being no information available to staff or management concerning what optimal performance of the task should look like. Indeed, from a management perspective, this was one of the main drivers for their participation in the research program.

AN EXPERIMENTAL PARADIGM TO EXPLORE LABEL-CHECKING PERFORMANCE

After gaining insights from the historical data, and interviews with key quality control personnel, the focus of the research program turned to exploring label-checking behavior experimentally under laboratory conditions. This allowed the approaches of naïve and experienced label checkers to be observed and compared under different conditions. This section begins by giving an overview of the simulated label-checking paradigm developed for the laboratory work. From there, the use of the paradigm to understand approaches to label-checking, to identify ways to guide optimal performance, and to determine whether different cognitive abilities might predict performance are considered in turn.

A gaze-contingent paradigm was developed to simulate the real-world task. This required the label-checker to have to shift their gaze alternately from the product specification sheet to the product label itself, thus moving visually between the two sources of information. The label-checking task was programmed in such a way that only one source of information (either the product specification sheet or the product label and any accompanying flash label) was visible on the computer monitor at any one time. If the participant's eyes were fixed on the top half of the display, then only the product specification sheet would be viewable. If the participant's eyes were fixated on the bottom half of the display, then only the product label could be seen. The number of fields of information was held constant at seven (these were product type, country of origin, name of the grower, quantity {either by number of fruit or by weight}, best before date {BB}, barcode, and flash label {promotion ribbon / label}; see Figure 2).

Having established an experimental paradigm with which to explore label-checking, the next phase of the research program involved recording the eye movements of professional label-checkers, employees of the packaging facility itself, who were brought into the lab in order to undertake the simulated task. The data so produced were analyzed to discover whether any individual differences existed in their label-checking strategies [2]. Accuracy of performance was measured, both overall (regardless of whether or not an error was present) and specifically in response to trials where there was a lack of congruence between the information presented on the product specification sheet and that appearing on the label (i.e., a label "error"). Some participants were found to have adopted a systematic approach to the task of label-checking, checking one piece of information at a time in a very serial fashion. Others took what could be described as being a "chunking" approach [5], in which the participants encoded and retained in short-term memory several bits of information from the label before checking them in the same visual pass on against the corresponding entries on the spreadsheet. A final group of participants showed no discernible pattern to their label-checking, being highly idiosyncratic in their behavior. There were, thus, differences in label-checking behavior. A "systematicity index", showing the number of intervening fixations between an individual fixating on a field containing an error and fixating on the field on the spreadsheet that corresponded with it, was calculated. This index indicated how directly the information on the label was compared with information on the spreadsheet and lower scores reflected a more systematic approach to label-checking. It was found that the four label-checkers with the highest error detection scores made significantly fewer intervening fixations than the four least accurate label-checkers. This indicated that a systematic approach to label-checking, in which one field of information on the label was checked at a time against its corresponding entry on the product specification sheet, produced the most accurate levels of performance in detecting labelling errors. In finding that different approaches were taken to label-checking by different professional label-checkers, the experimental findings were consistent with the interviews in which quality control operatives reported that no explicit instruction or training in label-checking has been provided at their place of work. This lack of formal instruction was borne out in the range of approaches adopted by the quality control staff, which varied in their effectiveness. The use of a particular strategy did not correlate with the number of years of experience that an operative had in the quality control checking of fresh produce labels.

Following the identification of different strategic approaches to label-checking, the next step was to see whether this understanding could be used to shape the behavior of individuals when carrying out the task. Some preliminary research was, therefore, conducted on 58 university students, who were naïve to the quality control checking processes involved in the checking of product labels [4]. Two blocks of label-checking trials were presented using a gaze-contingent eye-tracking paradigm. Depending on whether their gaze was centered on the top or bottom half of the monitor screen, the participants would see either the product label or the product specification sheet. This approach was taken in order to simulate the need for the label-checker to orientate visually between the label and the product specification sheet when performing a label check. In the first block of trials, the participants were allowed to follow their own personally determined method of label-checking. For the second block of trials, the participants were allocated randomly to one of three conditions. The first condition acted as a control condition, in which the participants were allowed to continue label-checking using their own idiosyncratic method. The remaining two conditions provided differing levels of computerized support to the participants. The support given by the first of these computer-guided conditions was unimodal, with visual highlighting of the current field of information which required checking. The second condition was bimodal with visual highlighting of the current field and a pre-recorded voice reading out the information presented in the field currently required to be checked. Improvements were seen in the accuracy of performance across all three conditions when moving from the first to second block of trials. However, significant differences were found in the extent of this improvement depending upon the experimental condition. Relative to the control condition, the bimodal support condition resulted in a significantly greater level of improvement (5% compared with 0.6%), while there were no significant differences between the control condition and the unimodal support condition nor between the control condition and the bimodal support condition. While a 5% improvement may seem small in absolute terms, this would translate to considerable savings in both financial and environmental terms. The empirical demonstration of the importance of releasing information to label checkers in a strictly serial manner was fed into the development of a commercially released software app called Greenlight Label Check. A three-month onsite trial of the app demonstrated the success of the approach, with the percentage of undetected label errors falling to 0%.

A further aim of the research program was to determine whether the accuracy of label error detection could be predicted by performance on standard laboratory measures of cognition. Findings in this area could potentially be used to guide personnel selection for the quality control role or to highlight the aspects of the cognition in which individual label-checkers would need to be supported. In broad terms, the literature with which the task of label-checking has greatest affinity is that of visual inspection, which also requires the checking products by eye for deviations from an accepted norm or correctness in one or more dimensions. The ergonomics literature has considered a range of different visual inspection tasks, such as those involved in X-ray security inspections at airports [6], aircraft inspection [7], contact lens inspection [8], international nuclear safeguard inspection [9,10], telecommunications [11], the manufacture of consumer products [12], and the production of pharmaceutical products [13]. However, unlike most visual inspection tasks, in which a manufactured item is compared against a mental representation of an exemplar stored in long-term memory, the quality control check of fresh produce labels requires two sources of information to be compared, both of which vary in informational content from check to check. There are, therefore, important differences in the structure of each task and associated cognitive demands, especially with respect to the demands made on short-term memory. In label-checking, unlike other types of visual inspection task, information from one source needs to be encoded and retained in short-term memory while it is compared with the information presented on the other source.

Alongside a label-checking task, Katz et al. [1] presented a battery of basic cognitive and perceptual measures to 51 university students naïve to the process of quality control checking fresh produce labels. Due to the time and resource constraints involved in testing a relatively large number of participants, the label and the product specification sheet were presented simultaneously on the monitor screen rather than using the gaze-contingent paradigm described previously. A battery of basic cognitive measures was also presented to the participants to measure information processing speed, attention, verbal and visuospatial short-term memory and working memory, and the propensity to mind wander. Of these measures, only verbal short-term memory was found to be a significant predictor of label-checking accuracy. The ability to recall a greater number of digits in the same order as they were presented showed a weak to moderate positive correlation with label-checking accuracy.

The observations and interviews described previously had highlighted the dynamic and complex pack-house environment. These findings suggested that label-checkers might draw upon higher-order cognition (or executive functions; e.g., [14,15]) in order to maintain task performance in the face of interruptions and distractions. Therefore, Smith-Spark et al. [3] administered executive functioning measures (the "core" executive functions of inhibition, updating, and set shifting; e.g., [15]) as well as a measure of the speed with which information could be processed to a mixed sample of professional label-checkers and naïve university students. Inhibition relates to the ability to prevent habitual responses in favor of responses that are relevant to task at hand and current conditions. Updating describes the ability to refresh the contents of working memory in the light of new information becoming available in the environment. Set shifting reflects cognitive flexibility and the ability to move fluently between different cognitive operations or cognitive sets. Information processing speed was measured in terms of the rate at which the participants could convert one form of information to another. Level of alertness was also measured using a subjective self-report measure which required the participants to rate their current level of sleepiness. The same gaze-contingent paradigm as described previously in this chapter was used to assess label-checking performance. It was found that better abilities on two of their battery of measures, namely information processing speed and inhibition, were related to better label-checking performance. Overall accuracy of label-checking performance (i.e., collapsed across trial types) was positively predicted by inhibitory ability, while the ability to detect label errors was also positively predicted by information processing speed.

METHODOLOGICAL CONSIDERATIONS AND FUTURE RESEARCH DIRECTIONS

While the verisimilitude of the simulated label-checking task to the task conducted on the pack-house floor was praised by the professional quality control staff taking part in the study, it should be noted that potentially important differences exist. Firstly, blocks of successive trials were presented. While the mean time to complete each label check was similar to that observed in situ, the presentation of label after label in an unbroken sequence was not reflective of performance in the pack-house, where quality control checkers would be engaged in other quality assurance work between label checks. While several labels might need to be checked in succession, a block of 50 label checks would be highly unlikely to occur.

Further to this, the number of fields presented on the label remained constant throughout the experiment rather than varying as it would in the pack-house. Work by Gallwey and Drury [16] has indicated that having more information to inspect results in reduced levels of performance. To add even greater verisimilitude to the task (and to explore the effect that the number of fields of information to be checked might have on performance), further research should explore this factor experimentally. In addition, the number of fields of information that could contain potential errors was limited to one. Gallwey and Drury [16] have found that visual inspection performance is lower when multiple fields contain an error rather than an error being present in only one field (see [16] for a review of the potential impact of this on performance). In the pack-house itself, however, each and every field printed on a label could, potentially, be incorrect, albeit with differing likelihoods of error occurring, and it would be the task of the label-checker to identify every error appearing on the label and not just the first error that they encountered.

The current experimental paradigm is not able to account for strategic behavior relating to participants exiting the label check after having found a single error. It would also be informative to explore the effects of distractors (such as unpredictable noises) on performance, given the difference between the controlled laboratory setting in which label-checking was investigated and the noisy and dynamic environment in which quality control checking takes place. The ability to maintain the goal of label-checking under these conditions would be likely to link to executive function and, as a result, it might prove fruitful to look at the association between performance under such dynamic conditions and measures of executive function, perhaps finding stronger links than those described in the previous section.

Harris [17] has highlighted the influence of the frequency of defects on visual inspection, with inspection accuracy decreasing as the rate of errors decreases. In the label-checking experimental paradigm, the percentage of trials containing a label error was 20%. The rate of errors had to be considerably higher than in the pack-house due to time and resource constraints on both the professional label checkers and researchers.

Owing to the complexity of label checking in terms of the cognitive and situational factors involved, laboratory studies can only go so far in teasing out key determinants of performance. The insights obtained from the current program of research depended on experimental design choices having to be made. These maximized the degree of similarity between the laboratory task and the real-world situation that it was designed to replicate but it was not possible to copy or analyze all in situ elements. Thus, differences exist in that the laboratory task involved the presentation of large numbers of trials in succession, constraints on the number of fields of information presented on the fresh produce labels, the presence of errors in solely one field, and the frequency rate of errors. These and other factors remain to be explored. The need to explore environmental influences on performance has already been highlighted, together with suggestions for further extending the investigation of cognitive factors contributing to label-checking performance. Further research might explore the contribution of individual differences in characteristics such as conscientiousness and motivation, to label-checking performance.

CONCLUSIONS

Overall, the data gained from a range of methodological approaches have indicated the need for standardized training for operatives involved in the quality control checking process in order to avoid idiosyncratic and often less effective label-checking strategies from being adopted. The research has also identified several cognitive abilities which may predispose some workers to be better suited to the role of label-checking than others. Higher levels of verbal short-term memory, information processing speed (involving the rate at which information could be converted from one form to another), and inhibition have all been found to be positive predictors of label-checking accuracy. Performance on measures tapping into these areas of cognition may indicate the degree of fit between an individual worker and the demands posed by structure and constraints of the label-checking task. Finally, the research program has demonstrated that the process of labels checking can be guided in ways that make it more effective, suggesting a software application-based approach to label-checking in which human label-checkers are pushed towards a serial and systematic approach to the checking of label information fields by the controlled release of information over time.

Through the study of behavior both in situ and in the controlled laboratory setting, this research program has advanced the understanding of factors that influence the performance of humans in detecting errors during quality control checks of fresh produce labels. The research described in this chapter is broadly applicable to any type of product label which needs to be checked by humans during the manufacturing process and/or distribution of packaged products to retail points and thereby helping to reduce wastage and the carbon footprint generated by manufacturing.

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