Applied Ergonomics 41 (2010) 150–160

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

Quality control in the optical industry: From a work analysis of lens inspection to a training programme, an experimental case study

Maryline Rebsamen [a], Jean-Michel Boucheix [a,*], Michel Fayol [b]

[a] *Université de Bourgogne, Laboratoire d'Etude de l'Apprentissage et du Développement (LEAD-CNRS, UMR 5022), Pôle AAFE, Esplanade Erasme, 21065 Dijon, BP 26513, France*
[b] *Université Blaise Pascal, Laboratoire de Psychologie Cognitive et Sociale, (LAPSCO-CNRS, UMR 6024), 34 Avenue Carnot, 63037, Clermont-Ferrand, France*

ARTICLE INFO

Article history:
Received 27 April 2007
Accepted 2 July 2009

Keywords:
Control
Expertise
Training

ABSTRACT

A cognitive work analysis of quality inspection in the optical industry has been carried out in order to devise a training programme. The task concerned the inspection of high quality human eyeglass lenses. We conducted an experimental investigation of defect detection and acceptability decision-making tasks in 18 experts and novice inspectors. Detection and decision-making were investigated together and separately in two experimental sessions. We showed the effect of expertise on reaction times and errors, and we described the cognitive processes of novice inspectors. On the basis of the processing differences between the two groups, a training programme for new inspectors was devised and described. Finally, training effects were tested.

1. Introduction

The purpose of the applied quality inspection case study presented in this paper was to describe the cognitive processes involved in a difficult visual inspection task utilised by experts and novices, in order to build a training programme. Such a programme was considered a necessity for both professional development of trainees and quality enhancement by a major international optical industry factory. The material to be inspected consisted of corrective optical lenses for peoples' eyeglasses. Several key inspection stumbling blocks arose from the material properties, the work situation, and the lack of structured training sessions for trainee workers.

Paradoxically, as quality constraints have grown in most working situations in many European countries, ergonomic researchers' interest in inspection studies has dropped dramatically. For 25 years, very few studies were published on this topic. In other countries, such as the USA, for example, research into inspection (and training) has continued, particularly in aircraft inspection and maintenance, essential for safety (Gramopadhye et al., 1997a, b) in using technology properties (Gramopadhye et al., 1998, 2000) or more recently, in virtual reality (Vora et al., 2002).

The present case study had a more modest approach in terms of applied ergonomics. We used a quality inspection model (Drury, 1992; Drury and Chi, 1995) in an experimental investigation of defect categorisation (detection) and decision-making by experts and novices, inside the factory and outside the laboratory.

Quality inspection tasks in industry have evolved over time. Initially, a specialist department situated at the end of the production process performed a quality inspection (Stephaneck, 1966). Subsequent constraints placed by the "just-in-time" organisational approach contributed to a reorganisation of quality inspection. This task is now integrated with other tasks carried out in productions lines (François, 1989; Liévin and François, 1997).

It would be trivial to assume that quality inspection merely consists of searching for and recognising defects, and making a decision in respect of its acceptability within quality limitations (Drury, 1992). However, it does not consist of simple separation of non-defective products from defective products. Rather, it attempts to ensure that these products conform to a specific tolerance threshold, as defined by the quality inspection department. The inspector's task is complicated because tolerance thresholds have to be taken into account; post-detection; this consists of evaluating the defect in relation to specific standards and of making a decision based upon these standards. And sometimes conformity standards vary. These judgment and decision factors necessarily involve the "inspectors' subjectivity", which sometimes leads to insecurity and stress. Because inspection requires a high level of concentration, sustained attention, and prior training, operators frequently consider the task to be difficult.

2. Inspection in the optical industry

In the optical sector under study, lenses are produced by injecting polymer into special moulds. The inspection activity is

* Corresponding author. Tel.: +33 80 39 57 65; fax: +33 80 39 57 67.
E-mail address: jean-michel.boucheix@u-bourgogne.fr (J.-M. Boucheix).

0003-6870/$ – see front matter
doi:10.1016/j.apergo.2009.07.004

part of an assembly – inspection task according to the chronology indicated in Fig. 1.

Lens inspection requires special physical conditions, particularly in terms of lighting. In the real working situation, each inspected lens is brought into the inspector's field of vision, as he/she sits facing a "black box", containing a fluorescent tube in front of which the lens is examined (Fig. 2). The lenses are round and transparent; the defect to be inspected could be located on the external surface of the lenses or inside. The size of the lenses may vary from 65 to 80 mm in diameter and from 10 to 16 mm thickness. There were a number of different defect categories.

Every lens is scrutinised. In order to clear the lenses of dust, material projections, and other particles, on their surface, the workstations are equipped with air blow guns (compressed air) and lenses are systematically dusted with special fabric cloths (imitation suede). The inspection is carried out alongside this procedure. This task appeared difficult and often a source of "slip-ups" for several apparent reasons, beginning with statistical studies, by the Quality Department and the operators.

The product is itself a source of uncertainty. A lens presents a certain thickness and a certain curvature, both of which vary. At times, lenses provide the same perceptive result as a magnifying glass, and the defects are all the more difficult, not only to track down, but also to locate in the mass and in the area of concern (core) of the lens. Another source of difficulty stems from the defects sought. Indeed, if some defects are easily detectable because they are very noticeable, the majority are very small, some tenths of millimetres. In addition, they are extremely diverse ("micro-grooves", free jet, white fleck, pollution, batch stone, cotton, etc…) and can assume various forms. Lastly, with regard to the standards established by the Quality Department, it is necessary to decide whether or not the defect is acceptable.

The decision depends on combining three parameters. The first of these is the default intensity. The Quality Department calibrated four levels, the sizes of which vary from a few tenths of a millimetre and all are less than a millimetre. The intensity is measured only for one or two types of defects (these are the most frequent), the other defects being unacceptable, irrespective of their intensity. The second parameter is the part of the lens containing the defect. Lenses have been "virtually" divided into three concentric zones ranging from zone 1 to zone 3 (Fig. 3). Zone 1, tolerates fewer defects than the other zones and those which are less serious. Zone 3, tolerates the most defects in terms of number and intensity, because the lens is systematically re-cut by the optician. Zone 2 is the intermediate zone between the two other zones. The third parameter is the limited number of acceptable defects in each of the zones and in general, on the lens' surface. Finally, two constraints are added: one is the monitoring time, limited by the production targets (a few seconds per lens, 5 s being standard); the other is the variation of the criteria for the rigorousness of the inspection standards. While some types of lenses are required to be completely free from defects or permit extremely minor defects, exclusively in zone three, other types of lenses may comprise more marked defects, even in zone two.

2.1. Why were we asked by the factory to carry out the study presented in this paper? And what was the problem to be solved?

In response to the first question, there were three main factors, with combined effects. Firstly, immediately prior to commencing

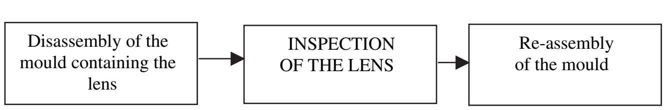

Fig. 1. Context of the inspection task.

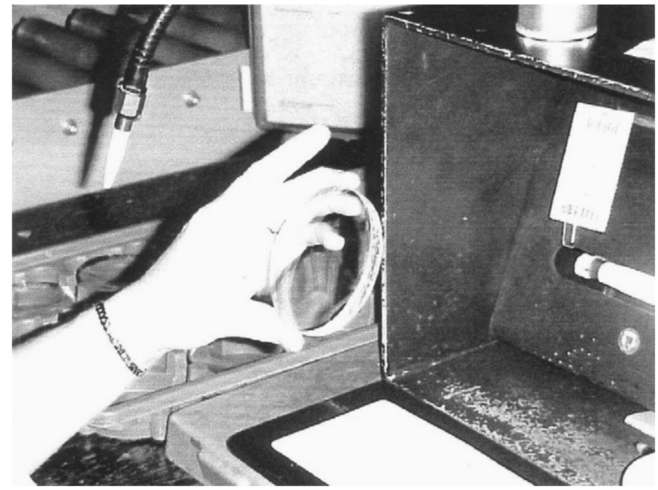

Fig. 2. Lens inspection at the workstation in the optical industry.

the study, the factory in which this analysis took place became an international pilot site where 400 workers were employed. Thus a great number of inspection trainees had to be trained within a short period of time. The factory was recently involved in obtaining a quality certification ("ISO 9002") which required employees, particularly inspectors, to reach a higher level of skill. At the same time, a new automated process of industrial mass production led to an important increase in the factory's output. Secondly, the initial task of the employees at this stage of lens production was the dismantling and re-assembly of the mould containing the lens. Thus, the task of inspection was added to the initial task. According to the inspectors' management staff, these changes did not affect experienced or expert inspectors performance, but did change to a considerable degree the performance of less experienced employees or novices. Thirdly, and this is the main reason, many inspection errors were observed, even after a long training period (more than several weeks). Due to the new organisation, including the new automated process, the average rate of defects was neither known nor expected by inspectors. Defects were not rare, so inspectors were really likely to find many defects. Within the same category of defect some were acceptable and in contrast others were not; and, depending on their size and on the zone where the defects were situated, i.e. on (or within) the lens, (Fig. 3) inspectors were required to alter their decision criteria. As indicated above, this implied that inspectors had to make a decision about which zone on the lens contained the defect. Moreover, the tolerance threshold (for size and zone, as well as for the different categories of defects) varied across different types or different

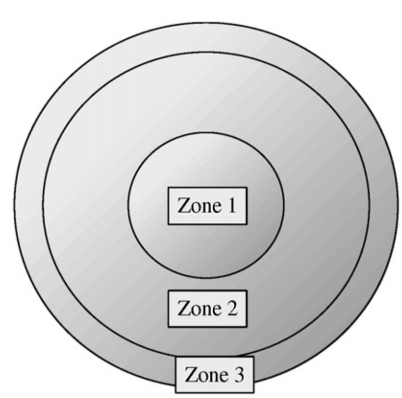

Fig. 3. Virtual lens areas.