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Effects of two ergonomic aids on the usability of an in-line screwdriver

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Abstract

We assessed the effects of two ergonomic aids on the usability of an in-line screwdriver. The simple aids considered were a hand support and a sleeve which softened the handle. In an experiment, 15 subjects drove screws into horizontal plywood plates with four combinations of a screwdriver and an ergonomic aid. The activities of four forearm muscles (EMG) and the force acting on the screw were measured. The subjects rated the properties of the tools as regards physical exertion, the ease of taking hold of the tool, comfort of the grip, and the surface texture. The hand support and the sleeve had positive effects on the subjective perception of exertion and the surface texture, respectively. Differences in EMG and thrust force along the shaft of the screwdriver handle were found to be too small for reliable deductions in the effects of the ergonomic aids.

Keywords: Usability; Screwdriver; Ergonomic aid

1. Introduction

The mounting of components with a pneumatic in-line screwdriver is a common task in assembly work. During screwdriving, the tool is pushed against the screw head in a vertical direction by using the power grip (Roebuck et al., 1975). In the usual setting, the tool hangs from a balancer suspended over the work area, and the worker grasps at it without taking his/her eyes off the piece under work. After the screwdriving task, the worker releases the hold on the tool. The physical exertion due to this part of the work depends on the number of repetitions, on the torque and on the thrust force along the shaft of the screwdriver handle, and the design of the screwdriver. The first two factors are more or less determined by the work itself, but there is some freedom with the last one. Besides lessening the physical exertion, good design may improve also the overall efficiency of the tool. For example, the need for a precise grip on the tool may mean several adjustments to the grip, which in turn implies diminished efficiency in frequent use.

There is no 'golden standard' for assessing the usability of tools. The ways to quantify the usability of a tool range from technical measurements to questionnaires. The choice depends on the items selected to represent usability. For some of these, a questionnaire is the obvious choice. For example, measuring 'comfort' in the technical sense is not possible. On the other hand, physical strain is directly related to external forces, and therefore a rough idea can be obtained by technical measurements. For a more detailed picture, one may measure the muscle activities related to muscle forces (Habes and Grant, 1997).

The objective of this study was to assess the effects of two simple ergonomic aids on the usability of an in-line screwdriver. One of the ergonomic aids was a hand support and the other a rubber sleeve for softening the handle of the screwdriver. A similar study, with somewhat different aids, has been described by Johnson (1988). Our study was initiated by the inventor of the hand support who needed experimental evidence of the benefits/drawbacks of the aid. Experimentation on the subject was felt to be relevant, as the replacement of the old generation of 'non-ergonomic' tools by the new generation of tools with improved ergonomic properties tends to be slow. Meanwhile, relatively cheap ergonomic aids may offer a way to improve the usability of the tools.

2. Material and methods

2.1. Measured variables

The usability of an in-line screwdriver was assumed to be affected by (1) physical exertion ('exertion'), (2) the ease

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of taking hold of the tool ('catching'), (3) the comfort of the grip ('comfort'), and (4) the surface texture ('surface'). These variables were assumed to depend on the characteristics of tools. The remaining controlled independent variables, such as the task, were kept constant in the experiment. The effects of the non-controlled independent variables, such as fatigue, etc., were minimized (as far as possible) by randomizing the order of using of the tools, and averaging over the set of subjects and repetitions.

2.2. Subjects

Fifteen healthy volunteers (10 men and 5 women) took part in a laboratory experiment. Their age ranged from 24–60 yr, and all the subjects were right-handed. Grip size was measured in the standard manner (DIN33402, 1978; Herig et al., 1964): the measure is the radius of the circle formed by the index finger and the fleshy prominence of muscle of the base of the thumb when gripping the standard Herig cone. The radii were between 11 and 16.5 mm, which covers well the usual variation of the working population. The subjects had no previous experience in using an in-line screwdriver.

2.3. Tools

Four different combinations of screwdrivers and ergonomic aids were compared: an old-fashioned model (Desoutter® 2D8-L) without ergonomic aids (A), with the hand support (B) and with a sleeve (C), and a modern 'ergonomic' model (Desoutter® SCO44-A-R5P) without ergonomic aids (D) (see Fig. 1). The old-fashioned model had triggers activated by a thrust force along the shaft of the screwdriver handle (push-to-start) and by pressing with the forefinger or middle finger. Simultaneous activation of both triggers was needed when using the tool. The handle of this model was cylindrical and made of metal. The contoured plastic handle of the modern rotation symmetric push-to-start model D fits the grip better than the ones of models A, B and C. Tools A and D constitute, in a way, reference points of a usability scale needed in the interpretation of the results of analysis. If model B or C turn out to be worse than model A, the corresponding aid has a negative effect and should not be used. On the other hand, if these models are better than D, replacement of the old-generation tools by the new-generation one cannot be motivated totally on ergonomic arguments as much cheaper aids do the same trick.

If the effect of the sleeve is not accounted for (about 5 mm), the diameters of the tool handles were about the same, i.e. 35 mm. This value can be taken as a good compromise between the optimal diameters with respect to gender, EMG, comfort, etc. (Ayoub and Presti, 1971; Hsia and Drury, 1986; Johnson, 1988; Pheasant and O'Neill, 1975).

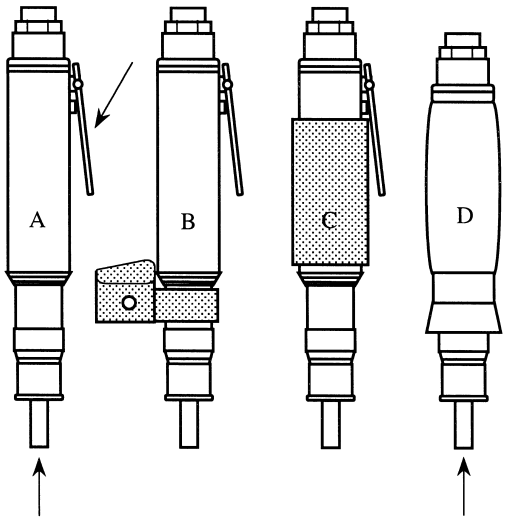

Fig. 1. The screwdriver and ergonomic aid combinations used in the experiments. Basic model A, the same with the hand support B, with the sleeve C, and the modern model D. The arrows show the triggers.

The hand support of tool B is essentially a ring, which prevents the hand from slipping downwards. A kind of wing or shelf, against which the hypothenar side of the palm is pressed, makes the aid asymmetric. Since the downward movement has been prevented with this aid, and the contact force between the aid and the side of the hand contribute to the torque, the gripping force needed should be lower than without the aid. The other aid, i.e. the sleeve made of rubber, makes the handle softer and increases the friction between the palm and the tool. The increased friction was assumed to decrease the need for gripping force. In addition, both aids were supposed to increase the comfort of the grip.

2.4. Task

The subject drove 5×70 mm screws into predrilled 3.5 mm holes in plywood plates. Each $120 \times 120 \times 15$ mm plate contained 24 screws positioned at equal distances on the perimeters of two squares with sidelengths of 60 and 100 mm. The plates were prepared by turning the screws of the outer perimeter to the depth of the plate thickness. In the preparation of the inner perimeter, the screws were turned once to a depth 60 mm, and then opened to the same position as the screws of the outer perimeter. Consequently, the torque was smaller on the inner perimeter. The mean values of resistance for the outer and inner perimeters were about 0.5 and 0.25 N m, respectively. These values are greater than the typical ones in assembly work, although the maximum values for men may be as high as 3–4 N m (Habes and Grant, 1997). Relatively large torques were used to improve the noise-signal ratio of the measurements, since small variations in the material properties, characteristics of the screws and the sizes of the predrilled holes produced variation in