A Check-List for Handle Design

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This checklist was first developed and published for surgical workshops in Sydney, Australia, in 1969 and has been revised since then at conferences in Israel, Australia, and the People's Republic of China.

A definitive version of this checklist, with line diagrams, was included in the Proceedings of the 1985 Victorian (Australia) Occupational Health & Safety Convention. A html version was published in Ergonomics Australia On-Line 11(2), 1997.

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WHY HANDLE DESIGN?

There will always be a need for well-designed hand tools and hand operated controls despite newer technology. Good handle design is important at work and in all kinds of daily activities for items that are efficient to use, safe, and attractive to buy.

Anything that can picked up by the human hand or which the body comes in contact with is in some sense a handle. All these need some of the same features, whether it is a door or a door-handle pushed open by the body, or a book or glass or box, or any of a hundred thousand other items.

The author of children's books about Peter Rabbit, Beatrix Potter, insisted her publisher made her books small, to fit the small hands of children, at the same time as the typeface was large to make reading easy. Like many expert and intelligent people she was an excellent intuitive ergonomist.

Newer demanding activities such as micro- and keyhole surgery have put more critical demands on hand-work than in the past. There is an even greater need to apply principles of good design to handles and understanding better how they are to be used.

There are other reasons for looking at the ergonomics of handle design for products. They are more likely to sell better when competing internationally with established manufacturers.

This article starts by looking at the common types of hand-grip, their features, and how they hold and use items. Most of the article consists of more than 50 criteria against which the design of a handle or hand-held item can be compared, and it includes ways of checking some features of handle design.

THE TROUBLES WITH HANDLES

Handles are often too small, too stiff, sharp, awkwardly placed, and confusing to use. Often only a little thought is needed to design or buy better tools and equipment. A simple check-list for handle design ought to be used by designers, buyers, and users of equipment of all kinds.

Despite the change in our society from an industrial to an information base, and from human to machine power, humans still communicate with machines by applying their hands or fingers to controls or keys of some kind. (Voice recognition and other modes for control have limitations including band-width, which will not be considered further here).

Even in the most advanced workplace, there are still many times each day when items have to be picked up and shifted, or handled in some other way. Too often the contact between hand and equipment is awkward, inaccurate, or unsafe. Bulky items like refrigerators and heavy office equipment still have to be gripped or pushed by human hand. The innards of a washing machine, or a motor engine, must have space in and around them for hands (and lines of illumination and sight) as well as tools.

For those more interested in robots than the problems of humans, some of the lessons learned from this aspect of the human-machine interface will help plan or improve the working relationship between robots and materials, a bionic approach useful elsewhere.

THE GENERAL HAND-MACHINE PROBLEM

The simple act of gripping a hand-rail to support the body can suggest the desirable thickness, length, and position of a general purpose handle, and perhaps some other criteria as well. However, individuals vary in how they grip according to their habit and size, and the same individual may vary the grip according to posture, force needed, other constraints, or for no obvious reason at all.

The problem of allowing for different grips can be solved by tailoring handles to different users and situations. This makes it even more important to have a general list of factors for handle design, which can be applied to different types of work and other activities.

It is necessary to begin by looking at ways in which humans grip handles. The two main ways are the power grip, for large heavy items, and the pinch grip, for small light items. Variations of these two make it worth considering five common basic grips, which follow.

TYPES OF HAND GRIP

Here these are considered as 6 types (there are other classifications, see eg., Mackenzie and Iberall 1994.

- Power grip
- Pinch
- External precision grip
- Internal precision grip
- Ulnar storage grip
- Other Power grip

Power grip

The fingers are bunched firmly around an object and overlapped by the thumb. The handle is thick enough to separate the finger-tips from the palm. (In this situation the forearm muscles have shortened half-way through their available range of contraction, and they are at their most efficient, because of the mechanics of the line of pull).

There should be a large area of contact, with no spots of local high pressure to prevent strength of grip being inhibited by discomfort. (This is like not being able to put your full body weight on the foot if there is a pebble in the shoe).

A common variant of the power grip is having the thumb out straight along the back of a handle. This is a 'power grip with a precision component'.

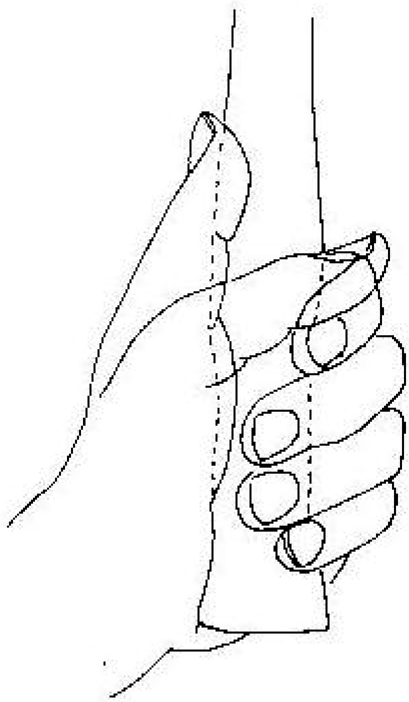

Fig 1 Power grip - thumb can be straightened as a precision component.

In holding a handle firmly in this kind of grip, movements arc carried out by the powerful muscles of the forearm, upper arm and shoulder, and not by the fine and delicate muscles in the palm of the hand. The positions of the finger joints are fixed by the shape of the grip, which further fixes the small hand muscles. There is none of the accuracy and control of fine movement which is available with the pinch or precision grips described below.

Pinch grip.

This grip between the thumb and the side of the index finger is used for picking up small objects, but not for manipulating them accurately, which needs the next grip to be described. Variants of the pinch grip include a flat grip for the edge of a dinner-plate, and many other finger postures which shade into one another. Small objects have to be gripped mechanically, with tweezers or forceps, or stuck onto handles such as the 'dops' used by diamond-polishers.

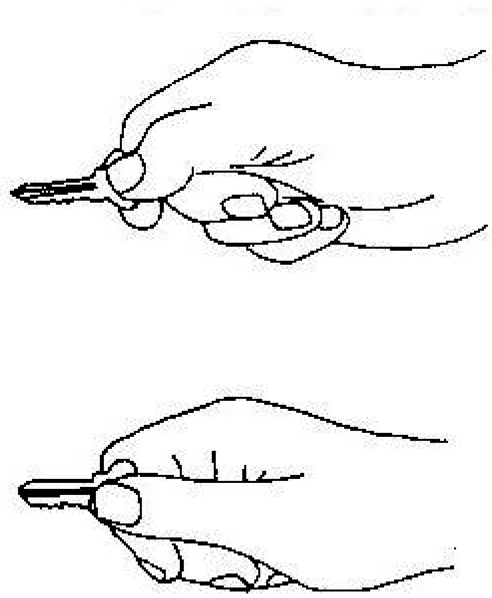

Fig 2 Flat variation of the pinch grip - stronger as it moves from the tip of the finger

External precision grip.

This grip is for fine work such as writing. It starts off with a pinch grip, but has the two extra components of support for the instrument in the cleft of the thumb and support for the whole hand along its medial edge. It is of special importance for microsurgery and micro-electronics (Patkin, 1977).

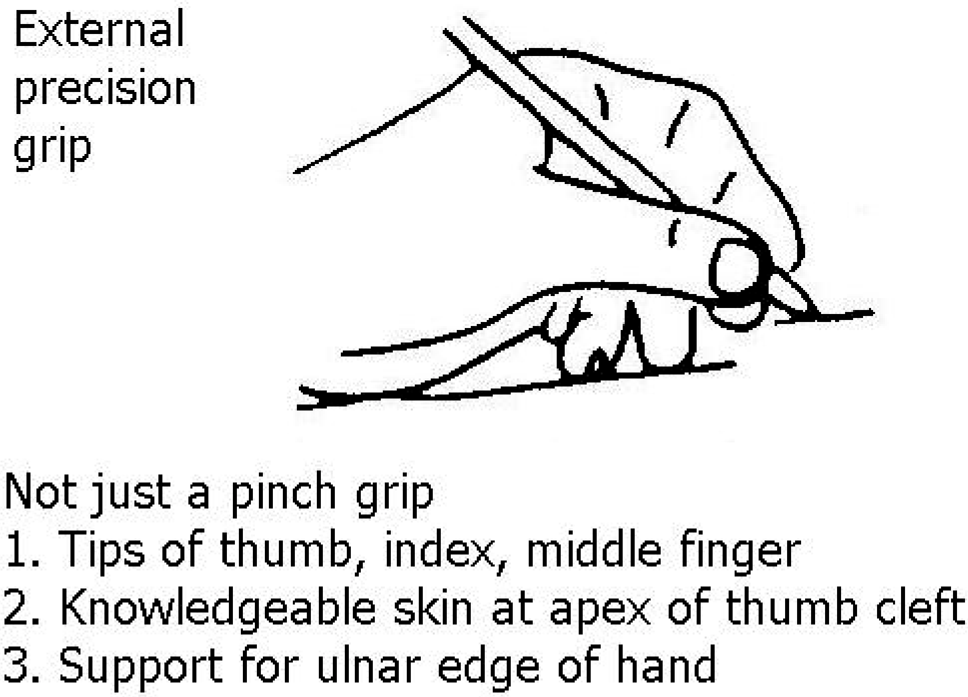

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Fig 3a External precision grip

Internal precision grip.

Unlike the previous grip, here the tool handle is held parallel to the work surface rather than at an angle to it. The hand may be steadied by the knuckles resting or moving on the work surface, or against the other hand, and there is less mobility in using the tool. This grip is used in delicate wood-carving.

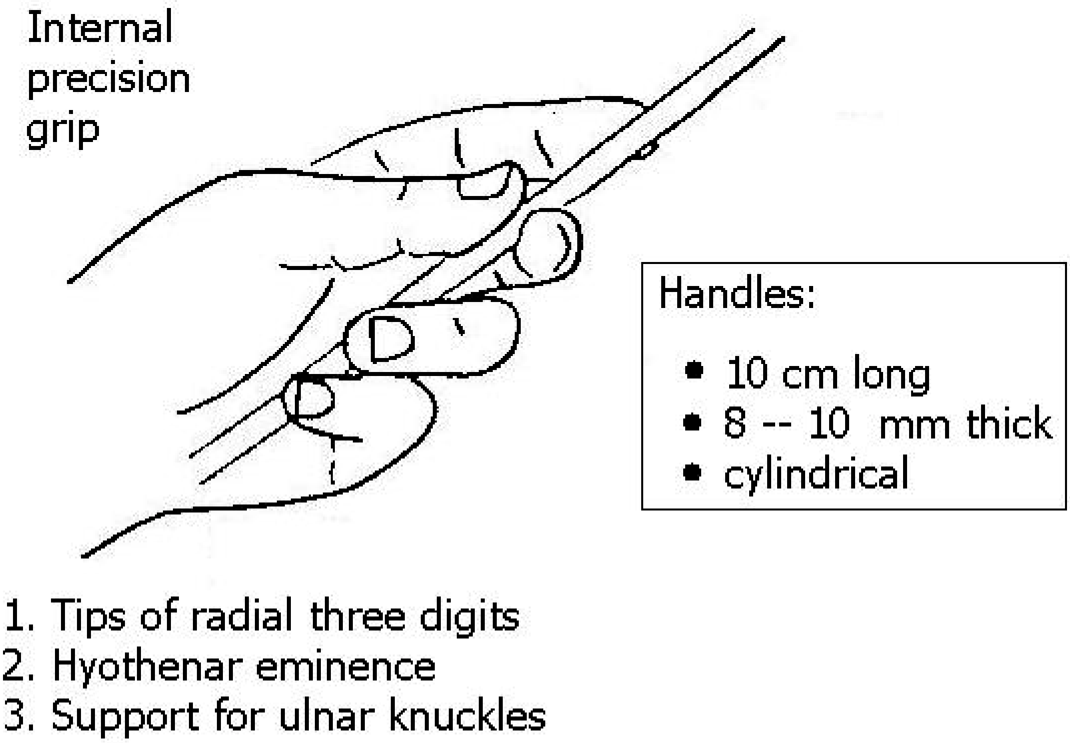

Fig 3b Internal precision grip

Ulnar storage grip.

I have applied this clumsy expression to a grip in which an item is stored in the little and ring fingers (for example the cork of a bottle) when the other three digits carry out some separate task (such as holding a glass). Simple examination of one's own hand shows that the end of something like a glass laboratory reagent bottle stopper should be 2 or 3 cm. long, about the same thickness, and also fulfil some of the other criteria in the long list that follows later.

Other grips.

Many types of hand grip can be described, such as the 'inter-digital grip' for a cigarette, several double grips, and dozens of others suggested by daily observation or ordinary activities. Other grips are used in highly skilled activities, for example the 'suture storage grip' of some surgeons, the various palming manoeuvres in conjuring, and keying manoeuvres in music.

What follows now is a general-purpose handle check-list for all kinds of hand tools, and for all kinds of items commonly picked up. It is based mostly on the power grip of the hand. It is easy to modify for the other hand-grips mentioned, and this will be demonstrated, as already mentioned, for instruments used in microsurgery and micro-electronics. Small changes in detail will be needed for different items.

THE ULTIMATE CHECK LIST FOR HANDLE DESIGN

There is no ultimate checklist. There are always more aspects of human activity to discover. However at any one time there has to be a solid interim foundation to work from. More than fifty criteria for handle design are grouped under 13 principal headings:

1. Size
2. Shape
3. Surface
4. Security
5. Stiffness
6. Siting
7. Surroundings
8. Signify function
9. Sensing features
10. Storage
11. Special other features
12. Skill needed
13. Validating design

1. SIZE

- Length at least 10 to 15 centimetres, to fit the width of the palm, longer for large-handed population, shorter if the butt end of the handle is to fit into the palm, when it should be rounded. Allow for the thickness of working gloves. The length of the shaft of the tool has to be looked at separately.
- Thickness, to allow the thumb to just cover the end of the index and middle fingers. For maximum power in an adult male, it should be 3 or 4 cm. in diameter (Drury, 1980)

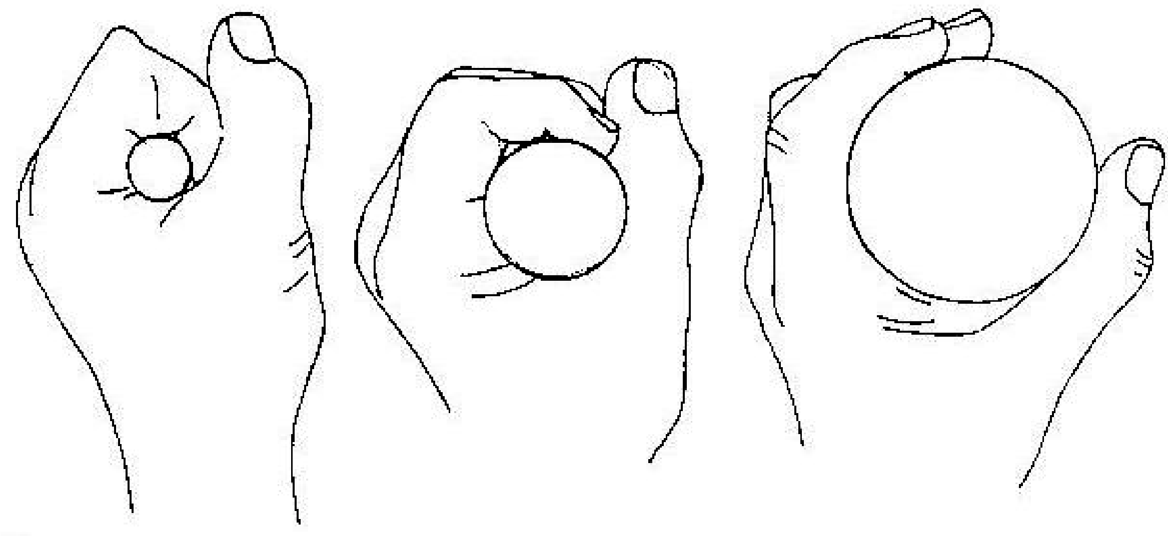

Fig 4 Handle diameter can be specified for strongest grip.

2. SHAPE

- Cylindrical, if the grip is to twist round the handle, for example a one-piece rolling pin. If the rolling pin has an axle inside it, the handle will give a more secure grip if it is a little flattened.

- Uniform diameter and smooth surface along the length, to allow sliding, for example on the back of an axe handle.

- Thickened centrally, if there is a need to secure against sliding. An example is a sheep-shearing hand-piece. This is not shifted within the palm, but there is much wrist and arm movement. Sweat and lanoline would make the grip less secure otherwise.

- Flattening for the thumb to straighten, and press on, and guide, as a precision variant of the power grip, e.g. a fine mallet or a fencing sword.

- Flattening for the thumb and fingers, to prevent unwanted twisting, for example a saucepan handle.

- No sharp edges or high spots in the area of grip. These decrease comfort, strength, and security of grip to an extent which can be measured. They may cause injury. However an edge or raised area is useful on the end of the non-grip area of the handle, for example away from the hot part of a frying-pan, to act as a guide to the safe position of the hand, and as a warning (see 'hilt' below).

- Shape coding for function, for example the controls on aeroplanes. (McCormick & Sanders, 1983, Chapter 9, Controls).

3. SURFACE

- Smoothness, mentioned earlier for sliding or rotating the handle within the hand. A smooth surface is better if it is non-reflective, to avoid glare in brightly-lit work. This is a common problem with surgical instruments.
- Roughness may be deliberate, for example towelling on a tennis racket. However knurling is often designed carelessly, so that it is ineffective or overdone as on the tops of some bottles and jars.
- Skin damage - allergy to nickel or nylon affects some people. Blistering and cuts may be a sign of bad design or overuse, but repeated use may be followed by the protective calluses typical of some occupations.
- Replaceability of the handle or cover, as wear occurs.
- Safety - insulation against heat, vibration, and electricity, and padding against sudden jolts.

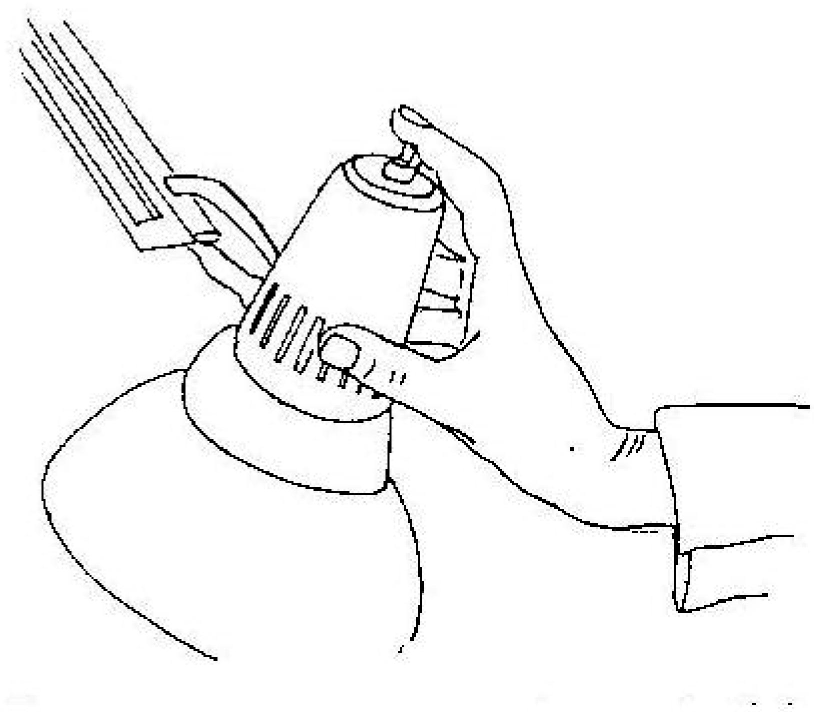

Fig 5 Switch designed to be turned off by people insensitive to heat

4. SECURITY AGAINST SLIP

- Pommel - an enlargement of the butt end, for security against slip, which would occur with momentary relaxation of grip.
- Hilt - a protection against sliding onto a sharp blade, or onto the shaft of a hot soldering iron.
- Central thickening (mentioned above, under 'shape') to allow the handle to be trapped in the palm when it is sweaty and slippery, for example a sheep-shearing handpiece.
- Gentle finger grooving, in some cases.
- Non-rounded (also mentioned above under 'shape') to stop a handle rolling off a sloping work-surface.

5. STIFFNESS (including resistance, weight and rotational inertia)

- The force needed to use a handle occasionally should be less than one-third of average possible maximum for the user population.
- Recommended values are found in standard textbooks of ergonomics or human factors, which should be on a handy shelf for anyone with a serious interest in design or use of handles.
- Typical values recommended area pull of 8 kg. on an arm lever on heavy equipment, 50 to 100 grams for the keys on an electronic keyboard, and about 2 kg. to close the ratchet on artery forceps. Pistol shooters in serious competitions have a detailed knowledge of how stiff triggers should be on different types of gun.
- Controls should be stiff enough to avoid accidental activation, by light brushing or by the force needed to pick it up. Too slack a control can be bad, for example the 'reset' key on older Apple computers, when it was next to the shift key. Accidentally pressing this could mean the loss of several hours of programming, with the exasperating need to repeat it.
- As additional safeguards, handles may be shielded by a cover, hinged bar, or protected by an additional trigger mechanism needing one or more fingers to work it.
- No slack, unless intentional.
- Clicking 'detent' positions, if appropriate, for controls.
- Planned 'feel' for rotational inertia, by concentrating the mass more at the middle or the ends of the tool.
- A deliberately chosen weight for the tool, taking any help gravity into account. Gravity effects may be exaggerated by centrifugal force or bumpy movements, and decreased or absent in an aerospace environment.
- Appropriate to the work context, there should be a heftier handle for tough material, and a more delicate handle for softer material, when the feel should be less diluted over a larger skin area. An example of this is the tightness of scissor blades, depending on how the screw joint is adjusted.
- The stiffness of a control should be well under the force to shift it or push it over. An example is an on-off push-button on the front of a light portable radio. (In this case the radio falls over instead of the control working when it is pushed).

6. SITING

- Within reach, and moving in the normal arc of body movement. (This is easy to check without having to refer to a book). Angled for normal wrist posture, to prevent sprains.
- Over, or just under, the centre of gravity.
- Not requiring body lean, or uncomfortable arm separation.
- Bench height - lower for heavier work, when body weight is applied to the work, and higher for fine work, when the forearms and wrists are supported, and vision is closer.

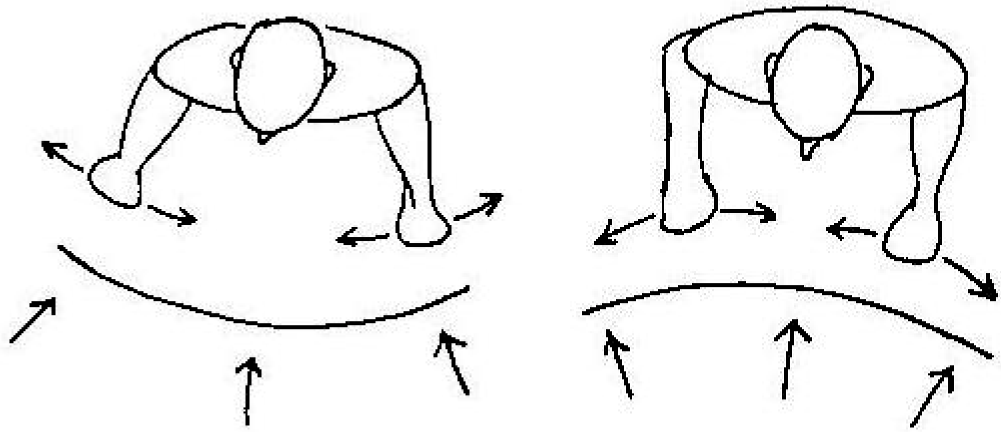

Fig 6 Human-centred and machine-centred arrangements of work

- This immediately brings in the question of chair height for seated work, also mentioned at the end of the next section.

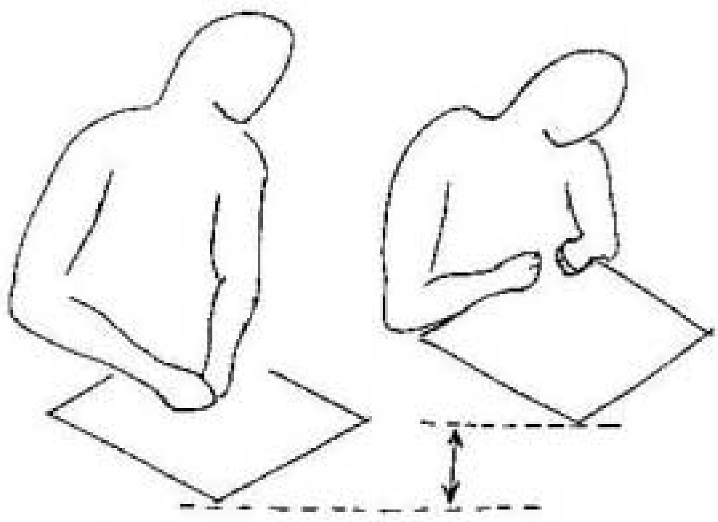

Fig 7 Higher bench for finer work

7. SURROUNDINGS

- Adequate clearance around the handle for access, avoiding finger damage on aperture edges, awkward posture, and obstructed line of vision.

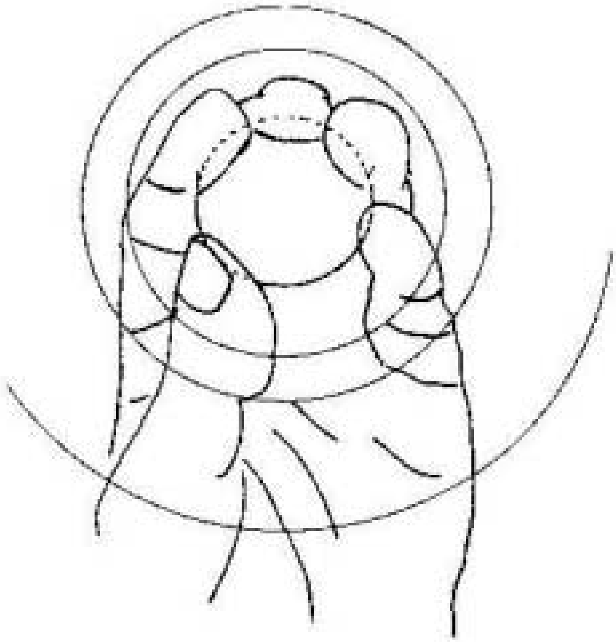

Fig 8 Clearance needed for fingertips, greater with more deeply recessed knobs.

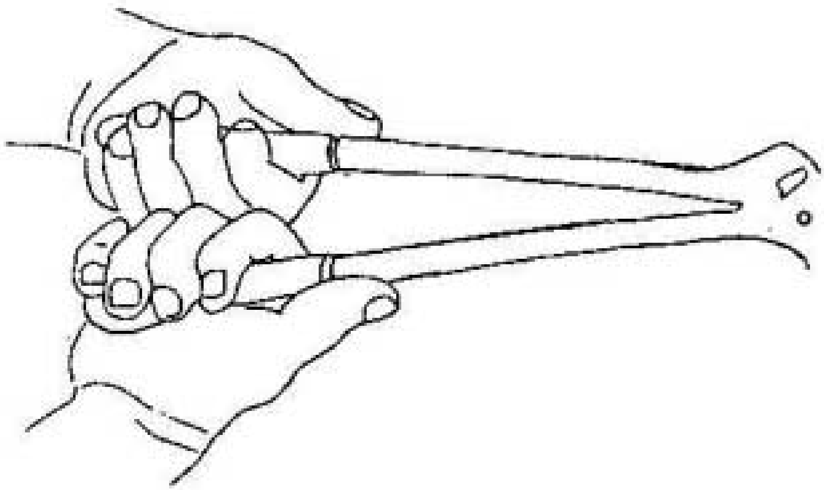

Fig 9 Plaster shears designed for orthopaedic surgeons who like banging their knuckles together.

- Protective shield - e.g. a knight's lance, the cover for the band on some hot flame torches such as the deseaming torch in the steel industry (an extension of the hilt listed above).
- Gloves, special-purpose protectors like a 'sailor's palm' for hand-sewing canvas, and the common thimble for sewing.

- Anti-tremor support provided by the bench-top during fine work, for the forearm, hand, and possibly fingers (for the 'external precision grip', mentioned earlier). Seating and the total work environment are involved.

8. SIGNIFY FUNCTION

- Shape coding (already mentioned) - scalloped edges for rotation, smooth edge for push-pull.
- Clear lettering or symbols on labels (Dreyfus, 1972). These should not become obliterated by wear.
- Ease of labelling - a flat and slightly recessed surface accepts writing or an adhesive label, with some protection against wear.

9. SENSING FEATURES

- Effect of using the control should be visible, palpable, or audible to the user, perhaps even smellable.
- The effect of use may be indicated by a special signal device - dial, warning light, or buzzer. The direction of movement of the pointer on the dial must be consistent with the user's expectation, and data is available for this.

10. STORAGE

- Provision of a hole, hook, loop, or narrowed waist for hanging up.
- Scabbard, drawer, other planned storage place.

11. SPECIAL OTHER FEATURES

- Cleanability - surface, crevices, cleaning compounds.
- Replacement, for wear, special users (children, left-handers, the disabled).
- Add-ons - for extra leverage, or thick gloves, or two-handed or four-handed use. Combining several functions in one handle.
- Individual needs of two-handled tools (for one or two-hand use), and special features for triggers and control buttons or slides.

12. SKILL NEEDED

- It is impossible to divorce the design of a handle from the attributes of the person who will use it, including their skill.
- To learn a craft well often takes some years. However there are many simple 'coded' movements that can be learned in a few seconds, and used then for a lifetime. It only requires that the movement be analysed and put into simple words.

  Such an example is steadying the two hands together to thread a needle, a simple element of movement which most skilled sewers are quite unaware of.

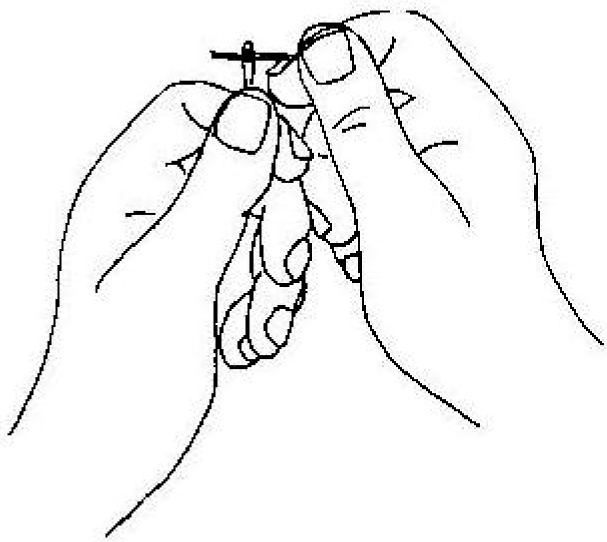

Fig 10 Skilled control of fine movement - steadying two pinch grips together

A sadly common example is the range of tense handgrips used by younger people when writing with a pen.

13. VALIDATION - CHECKING OUT HANDLE DESIGN

- The Mark 1, zero mode, naked eye-ball test. Does it look right?
- Does it feel right, consciously? Is the load comfortable?
- The wet slippery soapy hand test - will the handle feel secure without having to rely on friction?
- What is the maximum force that can be exerted on it? (This can be measured using instruments as simple as a kitchen scale and a bathroom scale).
- What is previous experience with such handles? Are there publications or catalogues or internet examples of them?
- Is the handle used in the expected way? (Some very "logical" handles fail this test).
- User tests - over a long time, with small or otherwise atypical hands.
- Staining tests, using ink on the handle or hand to show the areas of contact.
- Early warning from reports of accidents, tenosynovitis, or other injuries.
- Laboratory and research tests - electromyography (EMG), circulation testing of the hand and fingers (e.g. chicken pluckers handling refrigerated material, timber cutters using chainsaws in cold climates).

APPLYING THESE CRITERIA

This check-list of criteria is common sense put into a systematic form It is intended for the designer, the maker, the seller, purchaser, and user of handled items of all kinds. Where they find specific problems, they should seek help or further information from a professional ergonomist.

There are six questions to ask about all equipment and procedures1 including the design of handles and their use. While not original, they are worth repeating - what, where, how, when, and who - each of which is qualified by "why'".

Formal training in ergonomics is not necessary for assessing or improving handle design. The check-list just given should be enough, if combined with a critical look at the workplace, and the use of a few simple tools:

1. A standard reference (Grandjean 1980, McCormick 1976) or the guide published by the United States armed forces for its suppliers, MIL-STD-1472d.

2. A tape measure.

3. A cheap kitchen scale, a diabetic food portion scale, and a bathroom scale, for measuring forces applied to effect the desired action, including closure of handles.

4. Simple work-bench facilities for mocking up alternative designs.

5. Polaroid and 35 mm. cameras for recording examples of bad and good handle design.

6. Other questions of aesthetics and production costs require the help of imaginative designers and of engineers.

MUSCLE REPETITION INJURY AND HANDLE DESIGN

RSI, CTD, or CTS is discussed too widely elsewhere to get a lengthy description here. I consider it as due to 20 per cent ergonomics, 30 per cent medical muddle, and 50 per cent management problems and poor industrial relations. (Labels like carpal tunnel and tenosynovitis are thrown about, and often wrong. The danger is the victim may end up getting the wrong treatment, especially surgery.

The ergonomic factors can be summarised as:

STRETCH of muscles and ligaments to their extreme position, for example a very wide grip by fingers and thumb.

SPEED of repetition, and its duration, for example 12,000 keystrokes per hour instead or 8000, among some computer operators.

STRENGTH required or exerted, for example stiff handles on an espresso coffee machine giving 'espresso wrist', or a white knuckle grip on a pen which needs little force to write with (see next point). There are many similar instances.

(P)SYCHOLOGY - a background of mental and physical tension, giving a 'white knuckle' grip instead of a relaxed one just adequate for the task. Writing with a force of 500 grams weight instead of 20 to 50 grams weight may cause tenosynovitis, and may be prevented easily if properly diagnosed.

SUSCEPTIBILITY - of a group of people doing the same task, some will suffer strain or varying degree, and others will be quite unaffected. Those with previous injuries to the arm or neck are especially at risk, and so are people with hypermobile joints.

Why do abattoir workers suffer more from muscle repetition injury in a drought, on a Monday, and if they are not careful about their equipment? Some of the answers are - meat is tougher and from older animals during a drought, it has been refrigerated to a lower temperature and harder consistency after a week-end when the workers are also not warmed up, and knives which are not perfectly sharp take more muscle effort to cut with, with the added danger of skidding and cutting injury.

CONCLUSION

Man was described by the philosopher Tielhard de Chardin as a cerebro-manual creature. (He should have said cerebro-laryngo-manual, or cerebro-laryngo-manual-lots-of-other-things creature). The two hands form a system of two organs which is incredibly versatile arid fascinating, and also of continuing practical and economic importance. As a matter of interest the two hands are not equal. Their functions are quite different in many human activities, but that is another long story.

Although technology has developed other interfaces with humans, through voice, eye-movement, and even electroencephalography (EEG or brain-waves), the human hand will be a dominant feature of humans for millennia to come. Accordingly, careful design of handles will be important and worth-while, especially for demanding activities. A check-list such as the one presented here will need to be updated every two years or so, in accordance with new experience, information and new challenges.

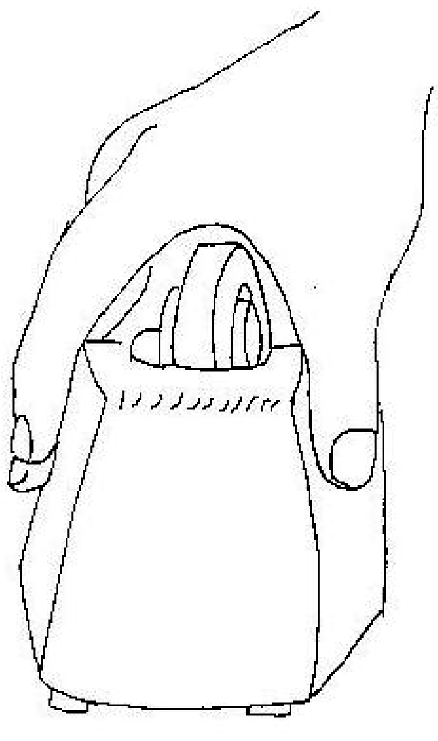

Fig 11 Sellotape dispenser designed to slip out of the hand grip

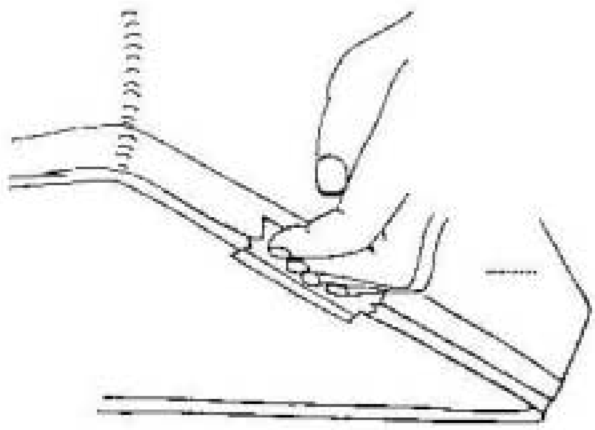

Fig 12 Tiny carrying recess on office equipment designed for steel-fingered pixies.

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