AUTOMATED TRANSDUCTION OF SHELTERED WORKSHOP BEHAVIORS¹

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This study describes techniques for attaching transducers directly to the tools in a sheltered workshop. The resulting automatic recordings of tool usage correlate fairly highly with independent measures of work products completed.

Tate (1968) described an automated system for reinforcing and recording retardate work behavior. The basic system consisted of a workspace with operant conditioning apparatus. The work task was mounting brass cylinders into 20 fuse holders on a plastic sheet wired in series which, when filled, completed a circuit signaling the programming apparatus to deliver pennies. Tate's system has now been expended by wiring a variety of workshop tools to programming and recording apparatus so that most of the work behaviors of the workshop can be transduced automatically.

Transduction of work behaviors occurs in the following manner. Since the workshop manufactures electronic equipment, most of the work is done by four groups of tools either singly or in combination: (1) pliers for grasping, cutting, stripping, crimping wire, or fastening nuts and bolts; (2) drivers, *e.g.*, screwdrivers, nut drivers, wrenches, files, drills; (3) solder tools, *e.g.*, soldering guns and soldering irons; (4) sorting devices for sorting according to size, length, and sequential order.

Transduction for the pliers makes use of either of two types of switches: (1) a simple wafer switch mounted at the fulcrum with Epoxy

cemented such that the moving parts move in conjunction with either arm of the pliers handle (See Figure 1a). Any of a variety of wafer switches (*e.g.*, Leviton) found in house lamps and available at most hardware stores for \$0.50 or less can be chosen to suit the size of the pliers. The top of the switch is discarded and the wafer is removed and fastened to the pliers by a small bolt through a hole drilled exactly through the center of the wafer and the fulcrum of the pliers. The switch housing and contacts (see inset) are fastened to the other moving part of the fulcrum with a fastening screw and Epoxy cement. The position of the wafer is then adjusted by twisting the bolt and tightening it into position with a nut on the opposite side of the pliers. This type of switch is durable, but takes about 6 hr to construct and requires some machining skill. (2) A much simpler type of switch was homemade and took only 30 min to construct. Two pieces of resilient metal were placed inside a small elastic insulating tube such that they acted as a ribbon switch, *i.e.*, they provided contact only when squeezed (See Figure 1b). The only materials necessary are a resilient metal (Controflex Ribbon Switch) and flexible plastic tubing (*e.g.*, Alplex PVC-105) available from Allied Electronics, Chicago, Ill. for less than \$5.00. Pieces of the metal and tubing are cut to size, assembled (See Figure 1b inset) and mounted between the plier handles just below the fulcrum so that closing the pliers provides contact closure and opening the pliers opens the contacts. Adjustment for degree of required

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Fig. 1. a. Diagram of pliers with wafer switch mounted. Inset: insides of switch. Turning the wafer closes switch contacts. b. Pliers with ribbon switch. Inset: enlargement of ribbon switch showing position of contacts sealed in clear flexible plastic tubing. c. Microswitch positioned inside the handle of a soldering gun. Squeezing the trigger operates the plunger of microswitch. d. Positioning of Controflex ribbon switch in nutdriver handle. For best operation one switch is embedded slightly in each of four sides of the handle. e. Diagram of soldering iron and solder clip. Clip is usually attached firmly to a bench vise.

pliers closure can be accomplished by simply moving the switch along the handle closer or further from the fulcrum. A plastic handle grip slipped over the attached wires holds the switch in place and keeps the wires out of the user's way. Total cost per switch is about \$0.30.

Both types of switch are highly reliable. The

wafer switch appears more durable but more difficult to construct. Pliers with this type of switch have been used for several thousand man-hours and still work well, whereas the ribbon switches have broken more with rough usage.

Driving tools also have been wired for transduction. Tools with the gun-type configuration are the easiest, *e.g.*, soldering gun, hand drill, *etc.* A microswitch (*e.g.*, Cutler-Hammer, 1sx1-T, Allied Electronics) is mounted inside the handle so as to close when the operating switch of the tool closes (See Figure 1c).

Tools with a vertical ratchet handle, *e.g.*, ratchet screwdrivers, nutdrivers, and wrenches can be wired by imbedding ribbon (Controflex, same as above) in the handle and covering them with a plastic insulating sleeve (See Figure 1d). To operate the tool, it is necessary to squeeze the handle. The same arrangement works with a file. These tools have the disadvantage that the item to be worked on must usually be in a stationary position, *e.g.*, a vise, so that the ratchet tool can be operated efficiently. Many retardates find the ratchet tools cumbersome because of physical handicaps. The use of the ratchet is necessary, however; for if the driving tool must be twisted, an expensive two-wire commutator is necessary to keep the attached wires from tangling.

An alternative to using a two-wire commutator is to arrange jobs so that two tools are necessary, *e.g.*, pliers and screwdriver. Then, the item to be worked on can be held with the pliers, which serves as one pole of the switch and the screwdriver with a one-wire commutator serves as the other pole. The circuit is then completed through the screw, bolt, lug, *etc.*, worked on. A brass fishing swivel serves as an adequate one-wire commutator as long as its moving parts fit snugly. Otherwise, partial contacts and arcing can occur with twisting of the wire.

Of the driving tools discussed, the latter method of transduction is more reliable and durable where twisting of the tool is involved. The ribbon switch is quite adequate for the file and similar types of non-twisting tools, however.

Transduction of soldering behavior is accomplished by attaching one wire to the chassis of the soldering iron and the other wire to a receptacle, *e.g.*, soldering clip, metal holders, etc. (See Figure 1e). Touching the item to be soldered held by the metal holder closes the circuit.

A variety of sorting devices have been constructed. For sorting by size, a large panel with different-sized apertures arranged in order was made. Below each aperture was a spring-loaded hinged plate with a microswitch attached. Below this panel was a matrix of plastic freezer containers of a size matching the apertures. Inserting the correctly sized item operated the spring-loaded plate and the microswitch for that aperture. Sorting by length can use a similar principle.

Some jobs involve the sequential assembling of appropriate items. Small bins with photoelectric beams above each provide a reliable switch closure whenever the beam is broken by inserting the hand. Sequencing can then be scheduled automatically.

A variety of other tasks have been difficult to transduce, *e.g.*, inspection and cleaning tasks. These, however, constitute a small proportion of the jobs performed by workshop employees.

Evaluation and interpretation of work behavior normally results in the following sequence. The employee is seated at a workspace with a feedback panel containing a counter, lights signalling when the program is in effect, when a tool is in use, and when a reinforcer is delivered, and a connector for attaching the transducers. He is then given an assembly-line job that has been graded for difficulty. Each workspace is independently programmed and rate variability. At the end of the work period, delivers reinforcements (light flash and counter tally) on a given schedule if the tool is in use at the appropriate time.

Reinforcements (tokens) for a work period are tallied by the workspace counter. Tool usages are recorded on totalizing counters and in cumulative record form at the programming console. Interresponse times are also taken on numeric printers as a check for reliability and response

the employee is paid the number of tokens tallied on his workspace counter, tool usages are recorded, and the number of work units completed; *e.g.*, wires cut, items soldered, studs fastened, *etc.*, are counted.

A problem arises in defining what are "true" tool usages and what are "inaccurate", "cheating" and other responses, *e.g.*, cleaning one's pipe or one's fingernails with a tool. Such extraneous tool usages occur in the sheltered workshop. In some cases they can be defined operationally. For instance, after baseline recording, the average interresponse time (IRT) of the employee's response rate can be an index of appropriate tool usage. If runs with IRT's far above or below a specified time window occur frequently, these can be programmed out automatically. Another restriction can be arranged in which a response is counted only when the tool contacts the work unit. Several other strategies exist to eliminate unwanted response patterns of a specifiable form through DRL contingencies, timeout, *etc.*

In the research performed thus far, extraneous tool usages have not been a problem because work units and tool usages were both recorded. Pearson *r* coefficients between tool usages and work units of each of nine employees were computed separately. For instance, the total number of plier closures and snaps crimped for each of two daily sessions, five days per week, for four months were recorded for an employee. This coefficient and those computed similarly for the other employees were all 0.70 or higher. Therefore, since both measures covary, it is assumed they are affected by the reinforcement contingency similarly. If they do not, an efficiency measure, *i.e.*, number of tool usages per work unit completed, can be derived and is itself a dependent variable of interest.

REFERENCE

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