A FORCE-TRANSDUCING MANIPULANDUM FOR USE WITH DOGS^{1, 2}

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In research utilizing dogs restrained in a device similar to a Pavlov frame (Kaplan, Campbell, Martin, Wulp, and Lipinski, 1962), we required a force-transducing pedal with the following specifications: (a) used in conjunction with a Sanborn carrier preamplifier and recording system, it registers a wide range of response forces; (b) its voltage output is linear over the entire range, and it can therefore be used in conjunction with an electronic threshold switch,³ enabling the experimenter to predetermine the force of response required to activate a control relay (*e.g.*, to trigger a reinforcement); (c) alternatively, force of response can be ignored as a variable for study, so that pressing on the pedal merely trips a microswitch to activate a control relay.

The particular concern was with the force levels that could be registered. The problem

was to find a force-transducer that could handle the higher forces likely to be exerted by an animal as heavy as the dog and still give linear voltage output. This requirement is not met by the transducers employed by Falk and Haas, 1965; Hefferline, Birch, and Gentry, 1961; or Notterman, 1959. However, the Grass FT-10 force-displacement transducer, when modified as described below, meets the specifications. It is a four element bonded strain gauge and linear over a maximum working range that extends to 10,000 g. Its cost is \$125.00.

A matrix of $\frac{3}{8}$ -in. diameter threaded holes in the steel floor of the restraining device enables the FT-10 to be fixed rigidly in place with a heavy brass mounting clamp, *MC* (upper diagram of Fig. 1) in the region of a dog's left or right front paw. Shielded cable from the amplifying equipment is attached to the unit with a Cannon connector, *CC*, and is protected by an aluminum plate (not shown). A portion of the transducer's cantilever beam, *CB*, protrudes from the casing and is shown in black. The lugs originally provided with the FT-10 are replaced by specially machined upper and lower lugs, *UL* and *LL*, shown in detail in section A-A of the figure. This is a cross-sectional representation of the unit, as indicated in the lower left diagram. Passing through the beam, the threaded tip of the lower lug is screwed into the upper lug. The top of the upper lug is also threaded and screws into the pedal, *P*, which is machined from hard aluminum-stock (shown in black, upper and lower right diagrams).

A metal pedal housing support, *HS*, is secured to the FT-10 with the same screws that hold the transducer's upper spring cover-plate in place. Attached to the housing support is a metal pedal housing, *PH*, whose top surface is 2 by $2\frac{3}{4}$ in. with a $1\frac{3}{8}$ -in. diameter hole. This opening is aligned with a $\frac{1}{16}$ -in.

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Experimental animals used in this study were handled in accordance with the Principles of Laboratory Animal Care promulgated by the National Society for Medical Research (Ref. -AR70-18, 20 Nov 61). The opinions expressed in this paper are those of the authors and do not necessarily reflect official Department of Army policy.

²We thank Richard Sparex for his diagrams of the device.

³A Dual Threshold Detector, compatible with the Sanborn system, was designed by Albert Sciorra and Nathan B. Marple, Electronics Research Laboratory, Columbia University. In this instrument, built from their circuit by Scientific Prototype Manufacturing Corporation, force thresholds are set in terms of percent of full load. Hence, the requirement of linearity for the various force ranges to be used.

Fig. 1. Diagrams of the manipulandum. FT-10: Grass force-displacement transducer; MC: mounting clamp; CC: Cannon connector; CB: cantilever beam; UL: upper lug; LL: lower lug; MB: mounting bracket; S: thumb screw; MS: microswitch; PS: pivot screw; ASA: adjusting screw assembly; P: pedal; PH: pedal housing; HS: housing support; AA: cross-sectional view of pedal, beam, and lugs.

deep recess in the pedal. Thus, for the pedal-press response to be executed, the dog's paw rests on the housing, and the center pads of its foot, extending below the housing surface, exert the pressure on the pedal. Under this arrangement, there is greater likelihood that

the cantilever beam will be deflected in a vertical direction rather than twisted.

When the modified FT-10 is mounted in the restraining device, it is positioned so that the lower lug protrudes through one of the floor holes without binding against the sides. The transducer is calibrated best with hanging weights that can be attached through a hole in the lower lug. It is very difficult to balance calibrating weights directly on the center of the pedal, particularly with the larger values.

If one wishes to ignore moment-to-moment records of force and desires the pedal merely to trip a microswitch when pressed, the switch, MS, can be fastened to the underside of the floor with a mounting bracket, MB, and heavy thumb screws, S (upper diagram and inset). Attached to its mounting bracket with a pivot screw, PS, and adjusting screw assembly, ASA, the switch can be raised and lowered by the adjusting screw. With the plunger of the switch properly aligned under the bottom edge of the lower lug, the distance between them may be adjusted as required.

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