Mechanical methods of controlling ataxia

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Ataxia means lack of order (Marsden, 1975). It has been described as a disturbance which, quite independently of any motor weakness, alters direction and extent of voluntary movement and impairs the sustained voluntary or reflex muscle contractions necessary for maintaining posture and equilibrium (Morgan, 1980). Ataxia can be resting, postural or kinetic (action tremor including intention tremor). It can be of sensory, cerebellar and/or labyrinthishine origin. More detailed descriptions of the causes and characteristics of ataxia can be found elsewhere (Holmes, 1922; Marsden, 1975; Morgan, 1980; Weiner, 1989; Gillespie, 1991).

Millions of people worldwide suffer from some sort of ataxia. Only a small proportion of these can be successfully treated with drugs or surgery. Tens of thousands of people are so severely impaired that they cannot perform essential tasks such as feeding themselves. Despite this, very little has been written about rehabilitation. This chapter describes the use of technology to enable people with ataxia to perform intended tasks. While some fairly sophisticated technological methods are described, it should not be forgotten that some very simple devices and adaptations such as special hand grips on pens and cutlery, non-slip mats and corrected seating positions can be beneficial for people with ataxia.

THREE WAYS OF REDUCING THE EFFECTS OF ATAXIA

It is important to define the problem carefully and flexibly. Solving a different problem from that originally defined may obviate the need to solve the original problem. (For example, the author was once asked to adapt a defective powered feeding machine for someone with 'limited arm movement'; instead he decided to try to control the ataxia in the person's arm using viscous damping (Michaels, 1986).)

The problem can be defined here as: how to enable a person with ataxia to perform a function such as lifting a spoonful of food from a bowl into their mouth. Figure 1 is a representation of the situation. A person with ataxia performs actions (a) such as contracting muscles to grip and lift the spoon in order to try to achieve the goal of putting a spoonful of food into their mouth. The person experiences feedback (b) from the weight and visual appearance of the spoon and their own arm. Figure 2 represents the
situation when technology has been added to the system in order to try to enable the person to perform the task successfully. Attempted technological solutions to the problem work in one or a combination of the following three ways:

1. Isolating the person from direct contact with the goal, so that intended movements can be acted upon while the superimposed unintended movements are ignored.

2. Effectively changing the quantity and/or quality of the feedback.

3. Applying loads, stimulations or constraints to the person with ataxia.

A successful technological solution to the problem must perform its function effectively, be aesthetically acceptable and convenient to use, create no significant adverse side-effects and be affordable. The solution must also cope with other impairments that may be present such as weakness, sensory and cognitive impairments. It must be acceptable to the person using it and to the people around them. Social and psychological factors can be as important as physical ones.

**ISOLATION FROM DIRECT CONTROL**

A person with ataxia can use voluntary movement to push a button in order to switch on or off an electrically powered machine or robot that has been built or programmed to perform desired functions. Feeding machines of this sort are available from the USA and from Delft University, The Netherlands.

Robotic devices are currently being developed by the Bath Institute of Medical Engineering and at Keele University, UK. These devices are primarily designed for people with very minimal or no arm movement at all. They are expensive, and many people find them aesthetically unacceptable. Many people do not find it acceptable to have certain functions such as feeding performed for them by a machine. Some have stated that they would prefer to be fed by another person.
Some people with ataxia in their upper limbs may have more co-ordinated movements elsewhere in their bodies. A more controlled movement of some other part of the person’s body can be used in performing the required task. The ‘Magpie’ is a device that uses cable linkage mechanisms that enable foot movements to be translated into the manipulation of a holder for a tool such as a spoon or a shaver. It was developed at Mary Marlborough Lodge, Oxford, for people who had had their arms amputated.

Electronic and computer systems can be used to filter out high-frequency electrical signals from a signal containing both low- and high-frequency components. A person with a fairly high-frequency tremor, say 5 Hz, of a fairly constant amplitude could use such a system with a computer joystick to perform functions requiring lower frequency movement such as moving across the screen to a target. Some measure of success has been achieved using such a system at the Massachusetts Institute of Technology (MIT) (Riley and Rosen, 1987). Success is limited by the varying amplitude of the tremor giving it an effect with a lower frequency range, and by the fact that many forms of ataxia can be of quite low frequency, e.g. cerebellar ataxia caused by multiple sclerosis is typically 3 Hz (physiological tremor is 9–11 Hz). Filtering at low frequencies causes unacceptable time delays.

High-frequency tremor can also be isolated physically by using vibration isolation (Michaelis, 1986; Broadhurst and Stammers, 1990). Figure 3 shows the mass \( m \) that the person with ataxia wants to move attached to the person’s hand by a spring of stiffness \( k \), and a viscous damper of damping coefficient \( c \). (A viscous damper is a device such as a shock absorber that has the effect of dragging a paddle through a thick or viscous fluid.) A system with a weak spring and little damping will transmit very little high-frequency movement to the mass. Very low frequency movement will be transmitted exactly through the spring. Very high frequency movement will hardly be transmitted to the mass, which will move out of phase with the hand. There will be a resonant frequency where the mass will move half out of phase with the hand and at a much higher amplitude unless the damping coefficient is increased. However, increasing the damping coefficient will increase the high-frequency vibration transmitted to the mass. Thus, again, effective vibration isolation is difficult to achieve when the unwanted tremor

![Figure 3. Simple vibration isolation.](image-url)
frequency is low and thus close to the frequency of the intended movement. Figure 4 shows a graph of transmissibility against frequency, where transmissibility \( T \) is the ratio of the movement of the mass against the movement of the person’s hand. The desired solution requires a transmissibility near 1 for the low frequencies of intended movement and a transmissibility near zero for frequencies approaching and above the frequency of the unintended tremor.

Figure 5 shows one alternative arrangement where the person’s hand is connected via a spring to the mass that they want to move; the mass in turn is

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**Figure 4.** Graph of transmissibility against frequency for simple vibration isolation. \( c_0 \), critical damping coefficient.

**Figure 5.** Alternative vibration isolation system.
connected by a viscous damper to a fixed position. Figure 6 shows the corresponding transmissibility curves for this system. Again, a weak spring and high mass are needed to obtain a low natural frequency.

Both of these mechanical systems alter the visual feedback to the person using them as well as altering the loading that they experience on their arm. (These factors are discussed below.)

Experimental devices incorporating combinations of vibration isolation mechanisms as well as direct viscous damping have been tried at the Bath Institute of Medical Engineering, (Broadhurst and Stammers, 1990). The devices have been successful in substantially reducing the tremor amplitude of a spoon compared to that of the handle of the device, particularly when using the model of vibration isolation shown in Figure 5. So far, the current devices have been aesthetically unacceptable to the people that have tried them. It was also felt that direct viscous damping should be included to provide tactile feedback to aid control and to decrease the tremor directly (viscous damping is discussed below).

**MODIFICATION OF FEEDBACK**

Feedback is an important factor in ataxia. The effect of feedback depends on what neurological condition is causing the ataxia and also on the psychological state or ‘cognitive set’ of the person with ataxia.

Some forms of ataxia, such as essential tremor, hysterical tremor, tension tremor, tremor involved in writer’s cramp, and exaggerated forms of physiological tremor, especially those induced by emotional factors, can be reduced using biofeedback techniques. Biofeedback techniques have been
used successfully to treat some people with these conditions. The treatment can have a lasting positive effect (Hosaka et al, 1987). For some other forms of ataxia, such as those derived from degenerative diseases or from cerebellar disorders, feedback can have very little effect or even a negative effect.

Experiments at Cologne University, Germany, have shown that some people trying to track a target cursor on a computer screen are more successful when their position cursor is absent from the screen (Sanes et al, 1988). Similar work at MIT has shown that some people are more successful at performing tracking tasks if high-frequency tremor is filtered from their response before it is displayed on the screen. Some people, however, had their performances reduced by this filtering because of the resulting unresponsiveness (Riley and Rosen, 1987). (It is notable that parkinsonian tremor changes its nature during sleep (Askenasy and Yahr, 1990).)

In a similar way, changes in mechanical loading will result in changes in feedback. The effect of this on the force exerted to produce the tremor has been investigated only to a limited extent. An experiment at MIT used a torque transducer to measure isometric wrist flexion extension torques. These were sensed and displayed for use in tracking tasks. The gain was varied in order to vary the amount of effort needed in the tracking pursuit. For people with intention tremor, it was found that the force magnitude of their low-frequency tremor was invariant for a given posture, regardless of the voluntary effort level required in the tracking pursuits. (Note that such an invariant tremor force will produce less error as the intended force required is increased.) The high-frequency physiological tremor force did, however, increase linearly as the amplitude of voluntary force increased. For people with essential tremor, both the large low-frequency tremor and the smaller high-frequency physiological tremor force increased in magnitude with greater levels of voluntary force (Adelstein et al, 1987). These results have led the experimenters to the conclusion that intention tremor is driven solely by an autonomous source in the central nervous system; whereas in essential tremor, peripheral factors such as reflex oscillators and biomechanical resonance play a role. Unlike parkinsonian tremor, the phase of essential tremor can be reset by mechanical perturbations (Lee and Stein, 1981). Prior physical work can increase the amplitude but not the frequency of physiological tremor (Brooke et al, 1985).

Mechanical loading can change the frequency of the tremor. Increasing spring stiffness can increase the tremor frequency; increasing mass can decrease the frequency. Viscous damping will have little or no effect on the frequency (Vilis and Hore, 1977). These show biomechanical resonance effects that are predictable from the theory given below. A physical loading regime that successfully reduces intention tremor will also result in less effect of the tremor being fed back to the person with ataxia. The work mentioned above, which indicates that reducing feedback can reduce intention tremor, would thus suggest that such a successful loading regime would reduce the magnitude of the force of the tremor as well as reducing the tremor displacement effected by this force. This author's experience of using viscous damping to control ataxia confirms this hypothesis, particularly with people with ataxia caused by multiple sclerosis and head injuries.
Some people with Parkinson's disease have a variable reaction to such loading; in some cases where a small amount of damping is effective, higher damping is less effective. Peripheral loading has been shown to vary the tremor frequency of people with Parkinson's disease. This work together with a simple computer simulation model suggests that fatigue of intrafusal fibres resulting from chronic stimulation by the gamma system might be one of the main causes of parkinsonian tremor (Fukumoto, 1985). Clearly there is scope for more work in this area with people with different pathologies.

**MECHANICAL LOADING**

A minimum amount of mathematics is necessary in order to understand the ways in which mechanical loading can modify tremor. The key variables are displacement amplitude (distance travelled) and force amplitude (the force applied). The displacement amplitude produced by a given force amplitude depends on factors including: the mass of the object, spring stiffness and viscous damping.

![Simplified model of a person's arm](image)

**Figure 7.** Simplified model of a person's arm.

Figure 7 is an idealized representation of the movement of a person's arm in one dimension in a horizontal plane, not influenced by gravity. The arm has a mass \( m \), and is connected to a fixed datum by a spring of stiffness \( k \) and a viscous damper of damping coefficient \( c \). Muscles are acting on the arm to produce a net force \( f \) which results in the arm's displacement \( (x) \), velocity \( (dx/dt) \) and acceleration \( (d^2x/dt^2) \).

The spring stiffness, viscous damping and mass properties of the arm produce reactions against the force \( f \) in proportion to the displacement, velocity and acceleration of the arm respectively. Thus, by balancing forces:

\[
f = kx + \frac{cdx}{dt} + \frac{md^2x}{dt^2}
\]  

(1)

Now, if the force is oscillating simple-harmonically (with amplitude F), this will result in a simple harmonic displacement oscillation of the same
frequency, although not in phase. If the amplitude of the displacement is \( X \) and the frequency of the oscillation is \( \omega/2\pi \), then at time \( t \):

\[
\text{displacement } x = X \sin \omega t
\]

(2)

differentiating:

\[
\text{velocity } \frac{dx}{dt} = \omega X \cos \omega t
\]

(3)

differentiating:

\[
\text{acceleration } \frac{d^2x}{dt^2} = -\omega^2 \sin \omega t
\]

(4)

hence:

\[
f = F \sin (\omega t + \theta) = X(\omega^2 \sin \omega t + c \omega \cos \omega t)
\]

(5)

where \( \theta \) is the phase angle between the force and displacement.

Hence (by Pythagorus) the ratio of displacement amplitude to force amplitude is:

\[
\frac{X}{F} = \frac{1}{\sqrt{(\omega^2 \sin^2 \omega t + (c \omega)^2)}}
\]

(6)

The natural frequency of the system (the resonant frequency with no damping) is \( \omega_n/2\pi \), where \( \omega_n = \sqrt{k/m} \). In most postures in the unloaded situation, the effective damping coefficient \( c \) and the effective spring stiffness \( k \) are small and have little effect compared with the inertia effect of the mass \( m \).

Loading can be applied in order to effectively increase the values of \( m \), \( c \) or \( k \), thus resulting in reduced displacement amplitude for a given force amplitude. An effective solution is one where displacement is decreased more dramatically at higher frequencies than at lower frequencies. This will allow low-frequency intended movements to be carried out virtually unhindered while suppressing the unintended higher frequency tremor.

A sophisticated apparatus to measure the effects of loading on ataxia consists of a handle attached to a potentiometer which is connected to a computer that can thus calculate displacement and differentiate to obtain velocity, acceleration, rate of change of acceleration and so on. This information is then used to control a torque motor to apply loads back to the handle. Such an apparatus was used at Cologne University (Sanes et al, 1988). A similar apparatus incorporating movement in two perpendicular planes, a loading manipulandum with two degrees of freedom, has been developed at MIT (Adelstein and Rosen, 1987).

**Increasing the effective spring stiffness \( k \)**

Loading a person’s arm with a spring means that a force must be applied in order to maintain a given displacement. If this force is significantly greater than the force in the tremor, then the displacement may be maintained more accurately than if the spring were not present. Work with a force-sensing joystick, referred to above, confirms this prediction (Adelstein et al, 1987). Using springs to control ataxia is very limited because range of movement is
severely restricted. It can however be effective in switches where a switch will operate only if it is pushed hard and thus only by the person’s intended movement and not by their unintentional tremor. Maintaining a position under spring-loading can be intolerable because of fatigue.

Constant loads can increase or decrease ataxia depending on the position of the person’s arm and the cause of the ataxia (Sanes et al, 1988).

**Increasing inertia by adding mass**

From equations (4) and (6) above we can see that for a given input force amplitude $F$, the resultant displacement amplitude $X$ will be unaffected by increases in mass $m$ when the frequency of oscillation $w$ is near zero. At much higher frequencies, however, $X$ will be greatly reduced by increasing $m$. This effect of the mass increases with the square of the frequency. Hence we should expect that increasing the mass $m$ will have very little effect on the low-frequency intended movement, but will significantly inhibit the unintended ataxic movement.

Work at Frenchay Hospital, Bristol, UK, has shown that strapping lead weights to a person’s wrist can decrease tremor significantly (Hewer et al, 1972; Morgan et al, 1975b). Weighting has been shown to be effective for people with moderately severe tremor, but little or no benefit has been achieved with mild or very severe tremor. The work found no correlation between the pathological diagnosis of the person with ataxia and the effect of the weights. Most people achieved an optimum reduction in their tremor with weighting in the range of 600–840 g. There was no apparent correlation between the optimum amount of lead required to reduce the tremor and the severity of that tremor. On removal of the weights, some people’s tremor was less severe than before trying the weights, whereas some people’s tremor was more severe. In one experiment inertial loads reduced tremor in three of four people but increased it in the fourth person. Tremor decreased linearly with inertia for just one person (Sanes et al, 1988).

Theoretically, adding mass to a person’s arm usefully to reduce severe tremor is problematic. In order to reduce the tremor by a factor of ten, the inertia of the arm must be increased by a factor of ten. In a practical device where use of a computer-controlled torque motor would be too expensive, this can be achieved simply only by adding mass. The person’s arm would thus become very heavy to lift unless it were counterbalanced, which would still leave a device that was not easily transportable. Another problem with increasing inertia is that while it inhibits acceleration, it also inhibits deceleration. This can result in problems with overshooting, even when using wrist bands of relatively low mass. These characteristics have been confirmed by the author when working with occupational therapists using weighted bracelets at the National Hospital for Nervous Diseases, London (Michaelis, 1986).

**Viscous damping**

One way of inhibiting or damping out vibrations in mechanical equipment is
to apply a shock absorber or viscous damper. When you are in a swimming pool you can move your arm in the water with about as much ease as you can move it in the air provided your movements are very slow. Moving it more rapidly or shaking at high frequency requires much more effort, however. The effect is more dramatic with highly viscous fluids such as treacle.

Equations (3) and (6) show that a large increase in the damping coefficient $c$ will decrease the tremor displacement amplitude for a given tremor force amplitude by an amount proportional to the frequency. Viscous damping will thus resist the unintended high-frequency tremor more than a slow intended movement.

A number of researchers have found that applying viscous loads can reduce ataxia significantly, although few results have been published. Work with a very small number of people with ataxia at Cologne University has shown that tremor amplitude can be reduced roughly linearly with increasing viscous damping (Sanes et al, 1988). The slight non-linearity was due to the great diminution of tremor caused by the application of just a small amount of damping. This conforms with the subjective experience of the author. Success has also been reported by Maki et al (1985), Riley and Rosen (1987), Morgan (unpublished data, 1980) and at the Rancho Los Amigos Hospital and the Ottawa Crippled Children's Treatment Center. Work at Chailey Heritage has shown some success with people with athetoid cerebral palsy, although some therapists have expressed concern that the loading of children with athetoid cerebral palsy can increase their muscle bulk and thus worsen their movement problems (Ring et al, 1980).

![Graph](image)

**Figure 8.** Graphs of vertical acceleration against time for the hand of a man with ataxia trying to perform horizontal movements with and without viscous damping.
Early work by the author showed dramatic reductions in amplitude of hand tremor by factors greater than ten. Figure 8 shows the vertical acceleration of the hand of a man with multiple sclerosis causing severe ataxia while performing horizontal movements with varying degrees of viscous damping (Michaelis, 1986). Viscous-damped devices are now produced on a commercial basis, enabling hundreds of people with ataxia to feed themselves and to operate computers. The damping could be applied directly to a person's arm as shown in Figure 9. However, this is difficult to achieve because of arm geometry, the problem of strapping the arm firmly enough to stop relative movement of skin to bones and joints, and because of the weight of such a device, although the weight of a viscous-damped device can be far less than the weight of the equivalent mass loading needed to achieve the same reduction in tremor. Most potential users of a damped device have said that such an orthosis would be unacceptable. A far more straightforward solution is directly to damp the tool that the person is trying to manoeuvre. Figures 10 and 11 show possible configurations of such a device.

Figure 9. Damped orthosis (diagrammatic sketch). Arm (A) strapped (B) into orthosis (C) incorporating rotational dampers (D).

Figure 10. Damped feeding aid (diagrammatic sketch). (A) Rotations damped using rotary viscous dampers; (B) simple mechanism to keep the spoon horizontal; (C) handle and spoon.
A device similar in configuration to that depicted in Figure 11 was constructed and successfully used as a feeding aid by a man with multiple sclerosis (Michaelis, 1986). Although the device was quite flexible and effective, it was considered obtrusive. It was thus decided to design a device that could be mounted on a table and would have shorter lever arms.

Figure 11. Damped device attached to a wheelchair. (A) Wheelchair; (B) ‘Shoulder’, two degrees of freedom (d.f.); (C) ‘Upper Arm’; (D) ‘Elbow’, 1 d.f.; (E) ‘Lower Arm’; (F) ‘Wrist’, 1–3 d.f.—holds different tools or a splint for the subject’s wrist.

Figure 12. The ‘Neater Eater’ feeding aid.
requiring smaller, lighter dampers. Figure 12 shows the ‘Neater Eater’ feeding aid. This device uses two rotational viscous dampers mounted at right angles, attached to a baseboard which can be clamped to a table. The lever arm can be held at any position along its length, thus adjusting the effect of the viscous damping. A spoon clips on to a tool holder on the end of the arm which is kept horizontal as the arm is lifted up by a mechanism inside the arm. The plate is specially made with a curled lip that allows food to fall on to the spoon when the spoon is pushed against it, and a spigot underneath the plate locates in a hole in the baseboard allowing the plate to rotate but not to be dislodged from the baseboard in normal use.

One of the reasons why the Neater Eater is successful for people with a very wide range and severity of disability is that some movements are restricted: the Neater Eater is a device with two degrees of freedom limiting the range of movement to within a hemispherical shell locus; the spoon cannot be tipped forward and is kept horizontal by the levelling mechanism, and the plate spigot prevents any movement of the plate other than rotation.

Positioning is very important when using the Neater Eater, so that the user can lift the spoon directly into their mouth without having to move the head at all. This prevents any intention head tremor. Some people need to practise with a head-rest or restraint in order to gain the confidence that their arm is steadied by the Neater Eater arm before being able to use the device without such a head restraint.

Most people with cerebellar ataxia find that when their arm is steadied by the Neater Eater arm, this also helps to steady the rest of their body. Many people with athetoid cerebral palsy, however, find that when their hand is steadied by the Neater Eater arm this can transfer some of the athetoid movement to the rest of their bodies. Thus, it would be impossible for them to lift the spoon into the mouth while they are still holding on to the arm. For this reason, a counterbalance mechanism has been developed which counterbalances the weight of the Neater Eater arm so that a person with athetoid cerebral palsy can lift the arm towards their mouth, then let go of the arm and lean forward to take the food off the spoon. This would be impossible for someone with intention head tremor.

The counterbalance spring can also be set so that it can take the weight of the user’s arm. This can help people who have some weakness as well as ataxia, but viscous-damped devices work by offering resistance to movement and thus cannot be used effectively by people who fatigue too easily. The counterbalance spring can also be used in conjunction with another spring which brings the arm forward. This enables someone who cannot achieve a lifting movement or who cannot grip the arm to use the Neater Eater by pushing the arm back and down to the plate; letting the arm come forward while their arm is resting on it to scoop up the food; pushing the arm back again; and then letting go so that the arm comes forward and up to stop at a position where they can take the food from the spoon. Thus the Neater Eater can also be used by people with some spasticity or other movement impairment. A guide adaption has also been developed which can translate a backward or forward push–pull to diagonal forward and up or back and down motion.
The Neater Eater has to be a fairly sturdy device in order to handle severe ataxia. Most people, however, do find it to be aesthetically acceptable and find using a viscous-damped device far more socially acceptable than being fed by another person or by a powered machine. It is perceived as a tool rather than a machine. Most people find the feel of the device to be pleasing as it smooths out their movements directly, making them feel that they are directly in control of the spoon. This gives direct viscous damping a clear advantage over less direct control methods such as mechanical vibration isolation or powered devices. As noted above, there is evidence to suggest that viscous damping may not only reduce the amplitude of oscillation resulting from a given tremor force amplitude but that feedback effects may actually decrease the severity of the tremor force itself when used by many people with ataxia.

The ‘MouseTRAP’ (Computer Mouse Tremor Reducing Apparatus) is a commercially available device, also developed by the author in conjunction with a student from the London College of Furniture and Design (Paish, 1990). Figure 13 shows the MouseTRAP, which enables people with ataxia to use a computer. The computer mouse slots into a holder which can be manipulated on a flat baseboard in two dimensions. The mouse holder is linked to two rotational viscous dampers by a linkage geometry that ensures roughly even damping in all directions over the range of movement required. The user can thus control the movement of a cursor on a computer screen. Software is now available for most personal computers that enables people to operate all functions on a computer, including entering text and run any program, just by using a computer mouse without the need for a keyboard. This enables people with severe ataxia who cannot use a keyboard to use a computer far more rapidly than they could by alternative
techniques such as single- or double-switch scanner controls. Sophisticated
software is now available that can speed up computer input considerably.

The reaction of both therapists and users to these devices has been
positive. As well as the social and psychological advantages of the independ-
dence achieved, the devices usually encourage healthy posture and practice
of movements.

Researchers at MIT have worked on the development of a viscous
damped joystick (Hendriks et al, 1991) and an orthosis using electrically
actuated particle breaks (Baiges and Rosen, 1989). For some subjects, the
viscous-damped joystick has yielded performance comparable to undamped
normal control (Beringhause et al, 1989).

OTHER LOADING REGIMES

The appliances used at Cologne University and MIT permit experimentation
with other loading regimes as controlled by the computer. For instance, a
loading that is proportional to the rate of change of acceleration, and thus very
sensitive to high frequency movements, could be tried. However, such
devices are unlikely to be practical for reasons of cost.

In practice the damping coefficient of most viscous dampers is not
constant, i.e. the loading does not increase linearly with speed; in most
dampers, the loading increases less than linearly with speed. The above
theory would suggest that it would be preferable if the loading increased
more than linearly with speed.

One effect of using rotational viscous dampers is that they provide
excellent lubrication and thus very low ‘stiction’ or starting friction. The use
of friction to control ataxia has been suggested (Durie et al, 1980). Figure 14
shows a graph of resistance against velocity for a friction damper. The effect
of the stiction can create more jerky movement than movement with no
damping. This has been shown in experiments by the author (Michaelis,
1986). However, a friction damper with low stiction may have some

![Figure 14. Graph of friction damping characteristics.](image-url)
beneficial effect in some instances. At Cologne University it was found that applying a constant load was beneficial for some people (Sanes et al, 1988).

Another more complex loading regime is the dynamic absorber. Some forms of ataxia occur over a very tight band of frequency. This can be discriminated against using a computerized system or by using a dynamic absorber, as depicted in Figure 15. It consists of attaching an additional mass

![Figure 15. Dynamic absorber.](image)

$m_a$ and $k_a$ chosen such that: \( \sqrt{k_a/m_a} = \sqrt{K/M} = w_a \), where $w_a$ is $2\pi \times$ frequency of tremor to be absorbed, $k_a$ is the absorber spring stiffness, and $K$ is the person's arm stiffness.

![Figure 16. Graph of response against frequency for dynamic absorber system.](image)

$\mu = m_a/M = k_a/K$. Tremor is completely absorbed at $w = w_a$, but note there is a frequency below this where hand oscillates wildly.
to the system via a spring. The spring and mass are chosen to resonate at the frequency of the tremor and thus absorb the energy of the ataxia. Figure 16 shows the resulting effect. Such a system would have to be substantial in order to control the tremor sufficiently; it would be complex to arrange mechanically for the required movements; and, from the author's experience, would be unlikely to provide as beneficial a feedback effect as viscous damping. However, the author is not aware of such a system having been tried.

SUMMARY

Currently, the most effective and practical way of controlling ataxia which cannot be effectively treated with drugs, surgery or therapy is to use viscous damping. Devices are available commercially that have proved very effective in enabling people with ataxia to feed themselves and to use a computer, functions that they could otherwise not perform easily, if at all. For most people with severe ataxia this is very important. Being able to feed oneself is a very basic and important social and psychological function. Access to computers is extremely useful in this age, particularly for people with disabilities that prevent them from performing other functions. Provision of such devices can be one of the most effective ways of using resources to enrich the lives of people with ataxia.

APPENDIX: MEASURING ATAXIA

Apart from conventional clinical grading (e.g. Benesh Movement Notation System) and drawing tasks, there exist many methods of measuring ataxia that have been tried. These include:

- Conventional computer interfaces such as: joysticks (Andersen, 1986), digitizing tablet (Elble et al, 1990), goniometers (potentiometers) (Brown and Nelham, 1977 (Chailey Heritage)).
- A system using twin coherent polarized light sources with unidirectional polarized light transducers (Brown, 1977 (Chailey Heritage));
- A system using orthogonal search coils in a uniform alternating magnetic field;
- A system using a telescopic wand with sensors on the length and direction of the wand (Brown, 1977);
- A system using a pulsed ultrasonic transmitter and four ultrasonic receivers (Brown, 1977);
- A technique using a Schottky Barrier Photo Detector (Findley et al, 1981).

It is now common to use linear accelerometers in the measurement and study of ataxia (Morgan et al, 1975a; Fukumoto, 1985; Michaels, 1986; Gresty and Buckwell, 1990).

More sophisticated devices, incorporating goniometric sensors in appliances that can apply different loading regimes, have been developed and used by Cologne University (Sanes et al, 1988) and in work headed by Dr Michael J. Rosen at the Massachusetts Institute of Technology (Rosen and Adelstein, 1984; Adelstein and Rosen, 1987b, 1990; Brongo and Rosen, 1991).

Electromyography (EMG) and the analysis of the low frequency range of the EMG envelope has also been used in studies of ataxia (Andreeva et al, 1985).

REFERENCES


