Factors Affecting Blind Mobility

by

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Abstract

This thesis contains a survey of the mobility problems of blind people, experimental analysis and evaluation of these problems and suggestions for ways in which the evaluation of mobility performance and the design of mobility aids may be improved.

The survey revealed a low level of mobility among blind people, with no significant improvement since a comparable survey in 1967. A group of self taught cane users were identified and their mobility was shown to be poor or potentially dangerous.

Existing measures of mobility were unable to detect improvements in performance above that achieved by competent long cane users. By using newly devised measures of environmental awareness and of gait, the advantages of the Sonic Pathfinder were demonstrated.

Existing measures of psychological stress were unsatisfactory. Heart rate is affected by physical effort and has been shown to be a poor indicator of moment-to-moment stress in blind mobility. Analysis of secondary task errors showed that they occurred while obstacles were being negotiated. They did not measure stress due to anticipation of obstacles or of danger. In contrast, step length, stride time and particularly speed all show significant anticipatory effects.

The energy expended in walking a given distance is least at the walker's preferred speed. When guided, blind people walk at this most efficient pace. It is therefore suggested that the ratio of actual to preferred speed is the best measure of efficiency in mobility. Both guide dogs and aids which enhance preview allow pedestrians to walk at, or close to, their preferred speed. Further experiments are needed to establish the extent to which psychological stress is present during blind mobility, since none of the conventional measures, such as heart rate and mood checklists, show consistent effects. Walking speed may well prove to be the most useful measure of such stress.

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Publications

Work included in this thesis has resulted in the following publications:

D. D. Clark-Carter, C. I. Howarth, A. D. Heyes, A. G. Dodds and J. D. Armstrong (1981) The Visually Handicapped in the City of Nottingham 1981: A survey of their disabilities, mobility, employment and daily living skills. Blind Mobility Research Unit, Nottingham.

D. D. Clark-Carter (1983) The Nottingham Survey of the Visually Handicapped. International Journal of Rehabilitation Research. 6,(4), 495-497.

A. G. Dodds, D. D. Clark-Carter and C. I. Howarth (1983) Improving Objective Measures of Mobility. Journal of Visual Impairment and Blindness. 77, (9), 438-442.

A. D. Heyes, A. G. Dodds, D. D. Clark-Carter and C. I. Howarth (1983) Evaluating the mobility of blind pedestrians. In W.J. Perkins (Ed.): High Technology Aids for the Disabled. Butterworths, London.

A. G. Dodds, D. D. Clark-Carter and C. I. Howarth (1984) The Sonic Pathfinder: an Evaluation. Journal of Visual Impairment and Blindness. Vol 78, (5), pp 203-206.

D. D. Clark-Carter (1984) Gait analysis with blind people. International Journal of Rehabilitation Research. vol 7, (1), 90-91.

Contents

Chapter I

General Introduction

1.1 Definitions

The term 'blind', as used in this country, is a legal rather than a medical description, and refers to those officially registered as blind. Its use does not mean that the person so described cannot see at all but that their vision is severely limited. Either their visual acuity is below 3/60 or their visual field is considerably contracted.

The World Health Organization has produced definitions for the terms 'impairment', 'disability' and 'handicap' (W.H.O., 1980). An impairment is any loss or abnormality of structure or function. A disability is a restriction or lack of ability to perform a 'normal' action. A handicap is a disadvantage resulting from an impairment or disability which limits or prevents the fulfilment of 'normal' roles. Throughout this thesis the term impairment will be used as an impaired person is not automatically either disabled or handicapped.

1.2 The extent of the problem

Prior to 1965 little was known about the mobility of the blind. This date is significant because it was then that a survey of the mobility and reading habits of the blind in England and Wales was undertaken (Gray and Todd, 1967). The survey was primarily concerned with those of working age. Accordingly, it concentrated on this group, dealt with only a small proportion of those aged between 65 and 79 years, and included no one aged 80 years or more.

The survey revealed that a high proportion of the blind never made independent journeys: among those aged between 16 and 64 years forty-seven percent did not travel unguided, while for the 65 to 79 age group the figure was fifty-eight percent.

Since the national survey was conducted work has taken place in three related areas of mobility. Firstly, the nature of blind mobility has been explored. Secondly, aids have been introduced which are designed to assist the blind pedestrian. Thirdly, evaluation techniques have been developed to assess the worth of these aids.

1.3 The Nature of Blind Mobility

The reason for such a poor rate of independent mobility among the blind is the inherent difficulty of the task. Firstly, one of the obvious differences between the blind and the sighted pedestrian is that, whereas the sighted person can gather at a glance much information about the route, the blind person has to piece together evidence gathered from a number of sources to build up a picture, or schema (Foulke, 1971). Blind pedestrians utilize sounds emitted by the environment, smells, wind direction, the texture and gradient underfoot, echoes, and as a last resort, they feel with their hands. Secondly, whereas visual information is likely to be unambiguous, different environmental configurations can produce the same signals to the other senses. The blind pedestrian is therefore constantly involved in formulating hypotheses about the environment, or, as Foulke (op cit) terms it, making probability estimates. Thirdly, the sighted pedestrian receives information about aspects of a route well before he physically reaches them - in other words he has 'preview' (Barth and Foulke, 1979) - while the unaided blind person has very little advance information.

Armstrong (1975) has identified three main areas in which blind pedestrians will have poorer mobility than their sighted counterpart: they will be less safe, less efficient and under greater stress. Less safe because they cannot guarantee that they will not hit obstacles or stray from their path and into the road. Less efficient because they cannot achieve the same speed as sighted pedestrians and can more easily become disoriented. More stressed because they have constantly to monitor their progress consciously.

To overcome these problems a number of aids to mobility have been devised.

1.4 Mobility aids

1.4.1 Canes

The simplest aid - the long cane (see Fig. 1.1) - is a variant of the white stick which blind people have traditionally used. It comprises a narrow aluminium tube which tapers from the top, where there is a crook and rubber grip, to the bottom where there is a nylon replaceable tip. It should, when held vertically, reach 4 cms. above the sternum. Due to the pioneering work of Richard Hoover (Hoover, 1963) a particular technique for using the long cane has been developed, and to teach this technique to blind people the profession of Mobility Officer has been created.

In 1966 the Midlands Mobility Centre (now the National Mobility Centre) was established in

Birmingham, for the training of mobility officers. (Alfred Leonard, a former director of the Blind Mobility Research Unit, was largely instrumental in introducing the long cane into this country. The present training course at the Mobility Centre is still based on Leonard's shortened version of the original Hoover method.) The blind pedestrian who is experienced with the long cane can gain information about surface texture and gradient, and about the presence (even possibly the nature of) obstacles which are approximately one to two paces ahead.

Two other canes are in common use in this country: the guide or Torquay cane and the symbol cane. The former is a shorter version of the long cane and is designed to be used in the same way as the long cane. The symbol cane, as its name implies, is not so much a travel aid as a means of symbolising the user's impairment to other pedestrians. Incidentally, a red band on a white cane denotes that the user also has impaired hearing.

There are two disadvantages of the cane, from a mobility point of view. Firstly, it does not give head protection. Secondly, as it only gives information about things which are less than two paces away, the pedestrian who is walking at the speed of a sighted person is forced to make abrupt stops and changes in direction when something is contacted with the cane. In an attempt to extend further the preview which a pedestrian has, a number of electronic mobility aids have been developed.

1.4.2 Electronic aids

The ideal of every designer of mobility aids for the visually impaired would be an aid which provided users with all the information which would be available to them if their sight were not impaired. In trying to achieve this aim designers meet two fundamental problems: how to interrogate the environment and how to represent the information so gleaned in a form which will be usable by the visually impaired.

Electronic aids fall into two basic categories: either they actively generate their own energy and receive reflections of that energy, as with the bat's sonar system, or, like the human eye, they passively receive externally generated energy. One advantage of having generated the energy in the first place is that problems of interpretation of the resulting signal can be simplified. For example, by knowing that a signal at the receptor is the one generated at the transmitter x msecs before and that the energy used travels at a specific speed, the distance of the object which reflected the energy can be calculated.

Passive systems, on the contrary, require far more complicated interpretation. For example, a 3cm cube at a distance of one metre will produce the same retinal image as a 9cm cube at three metres. Nonetheless, humans, even neonates (Bower, 1966), can distinguish between these images, but how they do so is unclear.

Artificial passive systems have been designed which generally use a video camera as the receptor (Bach-Y-Rita,1972; Deering,1982). To date they have only had limited success in overcoming either the problem of interpretation or that of presentation of the information to a user, and are far from being surrogates for vision. Most designers have preferred active systems, one of the first being based quite explicitly on a theory of the bat's perceptual system (Kay, 1962).

Both light and sound have been used as the transmitted energy in different aids and each has certain advantages and disadvantages. Light can be directed very accurately but travels so fast that, for the relatively short distances about which a blind pedestrian needs information, the time of arrival of reflected light cannot be used to judge an object's distance. One possibility is to use the intensity of the reflected energy as the index of distance; the Sunray, devised by Yeshwant Sunthankas, is an example of this principle (see Fig 1.2). One drawback to this approach is that the amount of reflected light which is received by the aid will be a function of an object's size and colour as well as its distance. Thus, the aid's signal does not vary consistently with an object's distance. In addition, if an object is uniform in reflectivity and larger than the transmitter's beam width then the aid will detect no change in distance as it approaches or recedes from the object. For these reasons ultra-sonics are the preferred form of energy in most existing electronic mobility aids.

However, while sound is slow enough to allow time of flight calculations, it shares another problem with light. Energy, when it reaches a surface, is both scattered and reflected. As the angle of reflection equals the angle of incidence, when the energy meets the surface at angles other than perpendicular only scattered energy returns to the originating aid. Smooth surfaces produce little scatter. There are surfaces in the environment which are functionally smooth to both light and ultra-sonics and which therefore cannot reliably be detected. This is particularly a problem in dealing with breaks in the pavement surface such as downkerbs and holes in the ground. Thus, active aids are only considered safe when used as secondary aids in conjunction with a cane, which <u>can</u> detect discontinuities in the pavement's surface.

After the type of energy to be used by the aid has been chosen, the designer still has the problem of how to represent information about the environment to a user. Kay (1963) designed his original aid - the Sonic Torch (see Fig 1.3) - to give the maximum amount of information. It was a hand held device with a standard range of up to approximately six metres (twenty feet), but with a shorter range of up to approximately two metres (seven feet) which could be selected - for use inside buildings. The energy it used for echo location was a narrow ultra-sonic beam. It produced an audible signal to represent objects within its range and the quality of audible display varied according to the distance, size and texture of an object. It responded to more than one object at a time and produced a continuously variable display.

An early evaluation of the Sonic Torch was carried out by Leonard and Carpenter (1964). They found that while young congenitally blind people were capable of using it, elderly and late blinded people found it difficult to use and were not keen to persevere with it. As the majority of blind people are elderly and have acquired their visual handicap later in life, not surprisingly the aid was not generally accepted. Heyes (1979) states that it was widely considered to be a failure, and it has since ceased to be produced. One reason it was felt not to have been a success was the difficulty experienced by the user in making sense of the display; given its richness, time was needed to interpret the signal. In fact, Armstrong (1973) found no evidence that the Sonic Torch was being used as anything more than an object detector; users appeared to be ignoring much of the content of the signal.

The disappointing results of the Sonic Torch caused some people to rethink the nature of electronic mobility aids. They argued that since the user only required limited information about the environment and since the successful strategy with the Sonic Torch was to attend selectively to those features of the display which were relevant, then much of the processing should be done for the user by the aid itself.

The Nottingham Obstacle Detector (NOD) embodied this philosophy (see Fig 1.4). The NOD (Heyes, 1981) is also a hand held device which employs a narrow ultra-sonic beam and gives an auditory signal to the user. It has a shorter range than the Sonic Torch (approximately two metres), reacts only to one object at a time (the nearest), and treats the distance of objects as though they were in discrete zones. This digitizing of space means that the display is not continuously altering. Thus changes of signal occur less frequently and are more distinct, and so should attract attention more successfully. The NOD was found to be simple to use and to need little or no training (Dodds et al, 1981).

Two attempts have been made to combine the advantages of a cane with those of an electronic aid. The C-5 Laser Cane (Benjamin, 1973) and the Swedish Laser Cane (Fornaeus, 1974) both have built-in transducers and are designed to be used in the same way as the long cane, but to provide additional preview, particularly of obstacles which are above ground level. Only one of these canes is in use in this country and this by a pedestrian who admits to feeling insufficiently confident in its use to allow his mobility with it to be assessed.

1.4.3 The Guide Dog

One aid which solves the problem of preview is the guide dog. The dog is trained to guide its handler around obstacles, holes in the ground, uneven ground surfaces, and also, if the handler is not too tall, overhangs. In other words, it acts like a silent sighted guide. However, there are three main disadvantages with this aid. Firstly, like any domestic dog, it has to be cared for and exercised. Secondly, it can restrict its owner's access to certain places. Two examples are underground stations which do not have lifts or stairs and the visitors' gallery of the House of Commons (ironically, on one occasion owner and dog were excluded when the House was discussing the right of visually impaired people to a mobility allowance). A third drawback of the guide dog is that it does not inform its owner of landmarks and alterations to the route. In consequence, guide dog users are less aware than other visually impaired pedestrians of the nature of their routes.

1.5 The Evaluation of mobility

In 1967 Leonard and Wycherley noted that there existed no generally accepted criteria of travel performance and that it was difficult to measure such a skill objectively. Since then a number of approaches have been attempted: Kay (1974a) utilized a series of artificial tasks, such as having the pedestrian walk through a slalom course; Strelow et al (1976), Ponchillia et al (1984), and Barth (1979) each had pedestrians walk within artificial laboratory based courses. The method preferred by Leonard and Wycherley, and the one adopted by the Blind Mobility Research Unit, involves the pedestrian in walking an existing outdoor route. The problem with artificial environments, particularly indoor ones, is that they lack many of the cues which a blind pedestrian will normally use.

Having established the setting in which mobility should be assessed the next problem was to ascertain which aspects of mobility are critical and how to measure them. Leonard and Wycherley (op cit) identified the following as tasks which an independent blind traveller should be capable of performing if he is to be considered competent:

The ability to

1. Move through a familiar environment
2. Move through an unfamiliar environment
3. Move at speeds equal to sighted
4. Travel a straight line mid-pavement
5. Detect end of blocks
   (i.e. realise when a turn was required)
6. Detect and anticipate upkerbs
7. Cross straight or correct veer
8. Detect and anticipate upkerbs
9. Make indentations
   (i.e. when crossing at a corner cross at a point where the pavement is parallel with the opposite pavement)
10. Pick up true path
11. Detect obstacles/landmarks
    auditorily-tactually
12. Sense environment auditorily/tactually

They added that the person should be able to do these things safely (not endangering self or others), reliably (able to perform the skill repeatedly under a number of conditions) and purposefully (not haphazardly).

This list highlights the problem of criteria. To use norms taken from sighted mobility as in item three may be unrealistic, particularly as many of the other items are only applicable to blind travel; sighted travellers will not need to maintain a mid-pavement position, nor will they necessarily make indentations prior to crossing a road. These are techniques which are specially designed to make blind travel safer. Thus if a blind person travels as though sighted, however safely, and if his mobility is assessed according to the above criteria, he may actually be penalized relative to the person who travels using recognised blind techniques.

To date this hypothetical situation has not arisen, because the important distinctions between sighted and blind travel are the differences in preview of the environment and the degree of certainty about the layout of a route. Thus, until mobility aids have been invented which can supply this form of information - they would be virtual surrogates for vision - it seems unreasonable to build sighted criteria into the definition of competent independent travel for the blind.

However, there still remains the problem of how to assess the remaining sub-tasks. Leonard and Wycherley (op cit.) suggested using a check-list, but two problems arise from this approach. Firstly, the skills are not of the same magnitude; for example, being able to travel through an unfamiliar environment is not comparable with detecting and anticipating kerbs. This leads to the second point: what weighting can the individual items be given such that scores of less than one hundred per cent have any relative meaning?

Armstrong (1975) has dealt with the first problem by developing a system of scoring which concentrates on more microscopic events. His technique is designed particularly for assessing the user of the long cane. As the vast majority of mobility aids have to be used in conjunction with the long cane, the technique has a wide application. Armstrong observed blind pedestrians, and noted those events which were significant for mobility and could be objectively measured. His list was comprised of:

cane contacts with the inner shore-line

cane contacts with the outer shore-line

cane contacts with obstacles

body contacts with the inner shoreline

body contacts with obstacles

incidents at kerbs

number of steps taken

time spent walking (actual walking time)

time on the route (overall time)

A measure termed the 'productive walking index' was calculated as a ratio of the last two measures, and indicated the proportion of time spent in purposeful activity.

In addition, he made a number of unsuccessful attempts to measure the extent to which the pedestrian maintained a central position on the pavement. More importantly, despite having identified stress as one of the three major factors in blind mobility, he failed to devise a measure of it. All but one of his measures - the productive walking index - involved simply counting events.

Armstrong chose a specific route, to be representative of most aspects of mobility, and used this as the test route. He subdivided the route, generally at road crossings, into a number of sections and scores on his measures were totalled for each section.

Armstrong's approach avoided the problem of evaluating an individual's absolute mobility. He was interested in seeing whether an aid or technique made a significant change in a pedestrian's mobility. To do this he required each person to act as their own control by completing the route twice: once with both the new aid and the long cane, and once with only the long cane; or, if a training method was to be evaluated, then once with the long cane prior to training and once post training. Thus Armstrong's technique is only designed to make statements about an individual's relative mobility.

The introduction of the long cane to this country, the establishment of the profession of Mobility Officer, and the development of electronic mobility aids have all occurred since Gray and Todd (1967) revealed the poor state of mobility among the blind. To see whether these developments had had the expected effect of improving the mobility of blind people, a partial replication of the national survey was conducted.

Chapter II

The Nottingham Survey of Visually Impaired People

2.1 Introduction

In 1978 the Blind Mobility Research Unit (Nottingham) carried out a survey of the visually impaired which was partly a repetition and partly an extension of the earlier national survey (Gray and Todd, 1967). The national survey had restricted its population to those registered as blind. In England and Wales each local authority maintains two registers of the visually impaired in their area: one for the blind and one for the partially sighted. The Nottingham survey included those on both registers.

In order to learn about the more elderly visually impaired no upper age limit was set upon those included in the Nottingham sample. As members of the Unit and a small group of trained interviewers were to carry out the survey, for reasons of resources, the sample was restricted to those living in the City of Nottingham. Among other topics, questions were included about mobility, reading habits, employment, and disabilities in addition to visual impairment.

2.2 The sample

All those eligible, in other words all those registered as visually impaired and living in the City of Nottingham, were approached by letter and were given the opportunity to decline a visit from an interviewer. Of the 1283 who were eligible only just over 10% (137) refused permission to visit them. However, a further 519 were found to be ineligible as they had moved from the area, been de-registered, had died, or were in some form of institution. The remaining 627 were visited and of these 571 were successfully interviewed: 366 registered as blind and 205 as partially sighted. Failure to be interviewed at this stage was mainly due to severe physical or mental illness.

Each subject was visited by an interviewer who asked questions in a fixed order and in the form dictated by a schedule of 140 items (see Appendix I).

2.3 Results

2.3.1 Demographic details

The sample was typical of the visually impaired population in terms of age, sight, presence of an additional disability, and age at onset of visual problems. Two-thirds of the sample were over retirement age. Nearly three-quarters of them could see more than just the presence of light. Nearly two-thirds of them had a disability in addition to their visual problem. Three-quarters of them had developed their visual impairment since they were twenty years old.

2.3.2 Mobility

Thirty percent of the entire sample claimed to make no journeys outside their home in a normal week. These figures can be put in perspective by two forms of comparison. Firstly, as the majority of visually impaired people are elderly and, as greater age brings an increased likelihood of additional disabilities, there is a need for comparison with the general elderly population. Secondly, there is a need to see if this figure reflects any improvement since the original national survey of the blind was reported.

Hunt (1978) produced a contemporary survey of the general elderly population in England. Her survey showed that only approximately five per cent of those aged sixty five years or older were housebound. The Nottingham Survey showed that the figure for the same age group among the visually impaired was forty per cent.

The proportions in the Nottingham survey who have a disability in addition to their visual impairment and in Hunt's survey who have a disability are similar: sixty percent and fifty-eight percent respectively. Both surveys obtained this information from their respondents rather than by seeking medical opinion. Obviously the subjective nature of this information makes comparison difficult as to the relative severity of the disability, but, among the Nottingham survey, under eight percent judge their additional disability to be severe enough to preclude any mobility. In other words, nearly three-quarters of the registered visually impaired who are virtually housebound (over twenty percent of the entire sample) do not give a physical disability as the reason for their immobility. Therefore, the presence of a visual impairment which is severe enough to qualify for registration frequently seriously reduces a person's mobility.

Comparison with the national survey of the visually impaired necessitates the production of two sub-samples from the Nottingham survey: those on the blind register aged between 16 and 64, and those on the blind register aged between 65 and 79. There was no significant difference between the two surveys, for either age group, in the proportion who travel outside their homes (16-64 years: chi-squared = 0.018, p = 0.88, 2-tailed test; 65-79 years: chi-squared = 1.443, p = 0.23, 2-tailed test; see Table 2.1).

a) 16 - 64 years

		Survey	
		National	Nottingham
		%	%
Went out during	yes	92.0	91.8
previous week	no	8.0	8.2
	Total	100.0	100.0
Base		1044	110

b) 65 - 79 years

		Survey	
		National	Nottingham
		%	%
Went out during	yes	77.0	71.3
previous week	no	23.0	28.7
	Total	100.0	100.0
Base		420	136

Table 2.1: The journeys made during the week prior to interview by members of the National and Nottingham Surveys.

A number of questions about mobility were common to the two surveys: for example, those which referred to the crossing of roads, the willingness to undertake new journeys, and the learning of new routes. On none of these questions was there a significant difference in the responses to the two surveys. It should be pointed out that there is no reason to believe that the findings from the Nottingham survey are atypical. Reaction to the report of the survey (Clark-Carter et al, 1981), from the blind and those who work with them, shows that it confirms the view which they already held (e.g. Thornton, 1982).

2.3.3 Cane usage

In seeking the cause of the lack of improvement in mobility in the decade since the national survey of the visually impaired two things are notable. Firstly, the very aids which had been introduced to improve mobility were only being used by a fraction of the population. Secondly, a large proportion of cane users are untrained. In fact, there was no significant difference between the surveys in the proportions who were using a cane or stick as a mobility aid (16-64 years: chi-squared = 1.062, p = 0.31, two-tailed test; 65-79 years: chi-squared = 2.348, p = 0.13, two-tailed test; see Table 2.2).

a) 16 - 64 years

		Survey	
		National	Nottingham
		%	%
Use a cane	yes	58.0	63.6
or stick	no	42.0	36.4
	Total	100.0	100.0
Base		1044	110

b) 65 - 79 years

		Survey	
		National	Nottingham
		%	%
Use a cane	yes	65.0	73.0
or stick	no	35.0	27.0
	Total	100.0	100.0
Base		420	122

Table 2.2: The proportions in the National and Nottingham Surveys who use a cane or a stick.

This lack of difference cannot be due to a ceiling effect (in other words, that the proportion using a cane in the two surveys may represent all those who needed to use one), for 66% of those in the Nottingham Survey with no better sight than the perception of light, and thus for whom the long cane is felt to be particularly useful, did not use any mobility aid.

The Nottingham survey revealed that the largest proportion of people who used a cane or stick, as a mobility aid, used the guide (or Torquay) cane despite not having received any mobility training with any aid (see Table 2.3).

	Whether mobility trained		
	Yes	No	
Guide Cane	16.9%	50.0%	
Other	18.5%	14.6%	
Total	35.4%	64.6%	100.0%
Base			130

Table 2.3: The type of stick or cane used and whether trained in its use.

2.3.4 Guide Dogs

At the time of the national survey it was the policy of the Guide Dogs for the Blind Association (GDBA) to restrict the age of their trainees to 60 years. Thus, Gray and Todd only reported figures of guide dog ownership for their younger sample (16-64 years). Comparison with the Nottingham Survey shows that among those in the same age group and on the register of blind people there has been a significant increase in guide dog ownership (X^2 = 15.23, $p < 0.001$, two-tailed test; see Table 2.4).

		Survey	
		National	Nottingham
		%	%
Guide dog	Yes	3.3	10.9
user	No	96.7	89.1
	Total	100.0	100.0
Base		1040	110

Table 2.4 The proportions in the 16-64 age group in the National and Nottingham Surveys who use a guide dog.

To see how typical the Nottingham sample was with respect to guide dog usage, an attempt was made to gather national statistics for 1978. However, a comparison was not possible for the following reasons. While the GDBA train all guide dog users and keep in regular contact with them, they maintain their statistics according to training centres - of which there are now six in the United Kingdom - rather than according to trainees' home area. Thus, it is not possible to restrict the figures to those living in only one part of the United Kingdom. Therefore, it is necessary to gather statistics for blind registrations in England, Scotland and Wales. However, there is no statutory requirement to maintain such a register in Scotland; although there is a less formal register, based on information from charitable institutions. In addition, neither the Scottish figures nor the GDBA figures include sub-totals for different age groups.

2.3.5 Electronic mobility aids

Fewer than two percent of those registered as blind had ever had experience of an electronic mobility aid, and only half of these were continuing to use such an aid at the time of the survey.

2.4 Discussion

Despite the introduction of the long cane to this country, the establishment of the profession of Mobility Officer and the greater sophistication of electronic mobility aids, there appears to have been no concomitant improvement in the mobility of the visually impaired.

Two questions arise from the Nottingham Survey. Firstly, why are so few visually impaired people making use of mobility aids? Secondly, how good is the mobility of those cane users who have not received formal mobility training? However, before either question can be addressed there is a need for further discussion of the development of mobility aids and the attempts which have been made to assess mobility.

Chapter III

Mobility Aids and Evaluation of Mobility

3.1 Recent developments in electronic mobility aids

Hand-held aids have the major disadvantage that they occupy the user's remaining free hand, while the other hand holds the cane. This problem has been solved in the next generation of aids by having the transducers mounted into spectacle frames.

Despite the poor use made of the Sonic Torch, Kay (1974b) did not accept that the information which it displayed was too complicated to be utilised fully. The next aid with which he was involved, the spectacle mounted Sonic Guide (Kay, 1973; see Fig 3.1), supplies the same information but gives a stereophonic representation of the azimuthal position of objects. Heyes (1984a), on the contrary, continued to argue for object detectors and produced a spectacle mounted version of the Nottingham Obstacle Detector, called the Sonic Pathfinder (see Fig 3.2).

The Sonic Pathfinder gives cruder details of azimuthal position of objects: objects to the right of the aid are signalled to the user's right ear, objects to the left are signalled to the left ear, and objects in the centre are signalled to both ears. The aid further filters the information which users receive in that it samples the three directions sequentially but gives priority to the central area. This means that if an object lies in the central area and within the aid's range, then the sequential sampling will cease and only information about that central object will be supplied; once the object has been negotiated the aid reverts to sequential sampling.

The argument about display complexity continues. Foulke (1971) calls aids which provide the maximum amount of information to the user environmental sensors while he describes those which merely indicate whether or not there is an object in the way of the pedestrian as clear path indicators. He, and others, argue that for the blind pedestrian to develop a complete schema of a route they need the rich content of the environmental sensor's display, and that although users of clear path indicators may navigate safely they will be passing through an environment which has no obvious structure for them.

However, the attempt to make environmental sensors appears to have failed. Armstrong (1972) used his procedure to evaluate the relative mobility of five pedestrians, with and without the Sonic Guide (which was known then as the Binaural Sensor). On only one measure - productive walking index - was there a significant difference between the two passes of the route, and then only for one pedestrian. Despite this, he concluded that 'there is little doubt that the use of the Binaural Sensor leads to a considerable improvement in mobility performance'. Thus, as Dodds (in press) points out, a time-consuming objective evaluation was performed but its results were ignored and replaced by subjective impressions. Nonetheless, there was no objective indication that the aid was being used as anything more than a clear path indicator. Kay himself conceded that the Sonic Guide, as an environmental sensor, may only be useful to a limited number of people. He states that '... the language of the aid is not easy for many to master completely.'(Kay et al, 1977). As a consequence he has produced a version of the aid with a much simpler display (Kay et al, 1977, op cit.).

3.2 Shortcomings in aid evaluation

A number of problems are highlighted by Armstrong's evaluation of the Sonic Guide, the main one being that the objective evaluation failed in its task, which was to measure the differences between the aids. Armstrong's subjective impressions were based on considerable experience of mobility. If he believed that use of the electronic aid was beneficial then why did the evaluation not demonstrate this? Firstly, his route, while long, had large sections where there was little opportunity for data to be collected from a competent long cane user. (An incompetent user would not have been taught how to use the electronic aid, and would probably not have been able to complete the route, anyway.) Secondly, there was no evidence that his measures were reliable. Thirdly, they were limited in their range; there was no measure of veer, and, more importantly, no measure of stress.

At this point it is worth mentioning a criticism which was made by the inventor of the Sonic Guide. Kay (1980) stated that there existed no '... criterion for assessing enhanced travel ability'. On being questioned as to his distinction between 'improvement' and 'enhancement' (Kay, 1981; Kay, personal communication) it became clear that he was referring to a person's awareness of an environment. In addition, he felt that enhancement could not be objectively measured as it may have no effect upon overt behaviour.

Thus, it was necessary to re-assess Armstrong's evaluation technique before it could be re-applied.

Chapter IV

Extension and Reliability of the Evaluation Procedure

4.1 Modifications to the Procedure

A number of alterations were made to Armstrong's original design. Firstly, a smaller route was chosen as having a richer potential for producing scorable incidents, while at the same time remaining a reasonable example the type of route which visually impaired individuals walk. Secondly, to counter Kay's (1981) criticism that an aid could provide enhanced awareness of a route but that this would not produce a concomitant change in overt behaviour, radio microphones were used so that commentaries could be taken from subjects as they walked the route. Thirdly, a method of scoring the pedestrian's position on the pavement was devised. (Stress will be dealt with later in this thesis.)

4.2 Reliability

The test-retest reliability of all the measures - including Armstrong's original ones - was assessed.

Most evaluations of the form undertaken by the Unit are very time consuming and can only realistically involve a limited number of visually impaired people. In addition, if a large number of subjects are required before an aid or technique shows a statistically significant improvement in quality of mobility then it is likely to be of limited value. Accordingly, it was felt that the reliability study should have a sample size no larger than those involved in a normal evaluation.

4.2.1 Subjects

Six subjects took part, three totally blind, and three mobility officers who were blind-folded; as part of their training Mobility Officers are required to achieve a high level of proficiency with the long cane.

4.2.2 Procedure

After hearing a description of the route and a sample commentary, each subject walked the test route on three occasions using only the long cane. The first pass was to familiarize them with the route and the remaining two were to provide the reliability data. Each pass of the route was videotaped.

4.2.3 Results

4.2.3.1 The original measures

A list of the measures in Armstrong's original evaluation procedure is shown in Table 4.1. The scores for each route section were summed to produce a total for each measure. This yielded two scores for each individual on each measure, and the scores were compared using Pearson's Product Moment Correlation. The criterion set for the acceptance of a measure as reliable was that it should yield a correlation which was significant at, at least, the five percent level on a two-tailed test. Three measures failed to reach this criterion: Total time taken to travel the route, the number of steps taken, and the number of body contacts made with obstacles.

Measure	r	probability (2-tailed tests)
Total Time	0.7881	0.064
Time spent walking	0.9072	0.009
Productive Walking Index	0.9401	0.003
Steps taken	0.7365	0.103
Cane contacts with obstacles	0.9092	0.008
Cane contacts with inner shore line	0.8848	0.015
Cane contacts with outer shore line	0.9246	0.005
Body Contacts with obstacles	0.7093	0.126
Body Contacts with inner shore line	0.9578	0.001
Kerb incidents	0.8882	0.014

Table 4.1 Test-retest correlations and probabilities of the existing evaluation measures.

Of the three measures which failed to correlate at the criterion level of significance, only one - the number of steps taken - is a real casualty. The total time taken over the route is merely recorded in order to calculate the productive walking index, which produced a highly significant correlation. Both body contacts with obstacles and kerb incidents are important measures of safety. Although the latter produced a significant correlation, neither involved many events, compared with the other measures. The lack of a significant correlation for body contacts with obstacles is probably a reflection of the infrequency of such events; none occurred on five of the twelve passes of the route (six subjects each walked the route twice). Despite their infrequency they are probably one of the most important measures in the evaluation. Accordingly, rather than discard them it was decided to see if a combination of kerb incidents and body contacts with obstacles was reliable. This proved to be the case: $r=0.9055$, $p=0.009$, 2-tailed test - the resulting score is termed 'major safety errors'.

4.2.3.2 Pavement Position

Armstrong, in his attempts to assess the degree to which a pedestrian could maintain a central position on the pavement employed some complicated techniques but met with little success. For example, the film of the pedestrian was passed through a mixer box which allowed an observer to superimpose and move a cursor on the screen. The function of the cursor was to track the position of three points: the position of the outer shore-line, the position of the inner shore-line, and that of the pedestrian. The information from the cursor could be fed into a computer and be used to produce a continuous record of the pedestrian's position relative to the other two points. The observer could only track one of these points at a time and so had to watch the film three times. Although labour intensive, this would have been a useful technique, but for the fact that the measure was reliant on the maintenance of a specific camera angle, which could often not be achieved.

As an alternative, it was felt that while an observer watched the film of the pedestrian they could use their own judgement to compensate for the camera angle. This could be achieved if the pavement was divided across its width into imaginary zones. An early multiple event counter, which could be driven by a number of keys, was used for this purpose. A given key related to a given pavement zone, such that when a pedestrian was judged to be in a given zone that key could be depressed until the pedestrian moved to different zone. The result of this assessment would be a set of numbers, each denoting the length of time which the pedestrian spent in a given zone. The mean of these numbers, weighted by the zone number, would be an indication of the overall position maintained by the pedestrian. And, more importantly, the standard deviation of those numbers would give a measure of the amount to which the pedestrian veered from that mean.

Initially seven zones were chosen but this was found to be too many for an observer to make meaningful distinctions between, particularly on narrow sections of pavement; five zones were subsequently tried. The position of the shore-lines was moved according to the presence of obstacles. Thus if an obstacle appeared on the outer shore-line, then the pavement width was considered only to extend as far as that obstacle. For, if a good traveller detected an obstacle and changed his pavement position to avoid it, and if the inner and outer shore-lines were not considered to be movable, then he would be penalized relative to the person with poorer mobility who simply bumped into the obstacle. Scoring was not continued when a pedestrian stopped walking.

The route was subdivided into a larger number of route sections, such that a new section commenced at each change in direction; there were seven route sections. This had two advantages: firstly, it provided sufficient degrees of freedom for a significant correlation to be possible; secondly, it made scoring more simple, for when the inner and outer shorelines changed their positions relative to the screen, mid route-section, difficulties were experienced in maintaining a one-to-one relationship between key and zone.

Two forms of reliability were assessed for this measure: the degree of agreement between two observers of the same pass of the route as made by one pedestrian, and the test-retest reliability of that measure over two passes of the route by the six pedestrians as judged by one observer.

Measures of agreement were obtained by performing Pearson's Product Moment Correlations. The inter-rater reliability of mean pavement position produced a correlation of $r = 0.9875$, $p < 0.00006$, 2-tailed test, while assessments of the standard deviation produced a correlation of $r = 0.8156$, $p = 0.047$, 2-tailed test. For test-retest reliability a single mean and standard deviation was computed for each pedestrian for each pass of the route. The mean pavement position produced a large positive correlation: $r = 0.9933$, $p<0.00006$, 2-tailed test. The standard deviation produced a smaller correlation which failed to reach the criterion probability level: $r = 0.6358$, $p=0.193$, 2-tailed test.

This measure has not completely fulfilled its promise. It is true that mean pavement position has a high test-retest reliability, but the more important measure of variability has not. It can be argued that good long cane users still find difficulty in maintaining a central and constant pavement position and that a good additional mobility aid should overcome this problem. However, to demonstrate this the standard deviation for a group using the hypothetical aid would have to be significantly smaller than when they were only using the long cane. No statement can be made about the aid's benefits in this respect if only some individuals improve using the aid, as the measure has such an inherent level of variability.

4.2.3.3 Verbal Commentary

A pilot study was carried out with three totally blind pedestrians who were asked to talk about what they perceived, and what they were thinking, as they walked the test route. It was soon found that a certain amount of priming had to take place in order that only comments which were relevant to mobility were included. Hollyfield (1981), in her attempt to investigate the cognitive maps which blind people develop, noted the need for directed commentaries. Accordingly, a sample commentary was tape recorded and this was played to each pedestrian before they walked the route for the first time (see Appendix II). Obviously the quality of a given individual's commentary depends upon their own linguistic abilities, but as each subject acts as their own control, under normal circumstances this is unlikely to be a problem; in any case, the reliability study would assess whether it was a problem. However, again following Hollyfield, when the safety person who always accompanied subjects judged it to be necessary the pedestrian was reminded that a commentary was required.

The same two forms of reliability were assessed for the verbal commentary as had been applied to the pavement position measures: firstly, the agreement between two observers of the same pass over the route by one pedestrian; secondly, test-retest reliability comparing the scores of a number of pedestrians over two passes of the same route and under the same condition - this was judged by one observer.

The two observers agreed upon the existence of nine useful statement categories, and the commentaries were coded on this basis (see Table 4.2). Correlations were calculated using Pearson's Product Moment Correlation for each category. Tables 4.2 and 4.3 show the categories used, the former giving the correlations and probabilities for test-retest reliability, and the latter those for inter-observer reliability. One category - comments about olfaction - was agreed upon but not included in the analysis as few of the subjects made such comments on either pass of the route.

Statement category	r	p (2-tailed test)
Surfaces	0.7962	0.060
Shorelines	0.9712	0.0003
Obstacles	0.7604	0.085
Kerbs	0.6667	0.165
Mobility comments	0.9601	0.001
Sounds	0.9802	0.0001
Stating hypotheses	0.9121	0.007
Confirming/ disconfirming hypotheses	0.9132	0.007

Table 4.2 The correlation between the judgements of two listeners to the same verbal commentary.

Statement Category	r	p (2-tailed test)
Surfaces	0.8680	0.022
Shorelines	0.9818	0.00006
Obstacles	0.9434	0.002
Kerbs	0.7008	0.134
Mobility Comments	0.9134	0.008
Sounds	0.9574	0.001
Stating hypotheses	0.8246	0.042
Confirming/ disconfirming hypotheses	0.9504	0.003

Table 4.3 The test-retest reliability coefficients of the verbal commentary.

Two of the categories which failed to reach the criterion level of significance for the inter-observer reliability - surfaces and obstacles - were sufficiently close to that level that they are still worth recording, with a proviso about their significance level. One measure - kerbs - failed to reach the criterion level of significance on both forms of reliability, and by a sufficient margin that it is not worth retaining.

4.3 Conclusions

Most of Armstrong's original measures proved to be reliable, as did the majority of the elements identified in the verbal commentaries. However, given that only six subjects are used in such evaluations, the measure of the variability in a pedestrian's pavement position will only yield information when the two conditions being compared are so markedly different that every pedestrian in the study shows less variability in one condition than they do in the other.

The reliability of the measures has been assessed, the next chapter deals with the question of their validity.

Chapter V

The validity of the Evaluation Procedure

5.1 Types of validity

The question of validity is by no means a simple one. House (1980) has tried to distinguish the goals of evaluators, in order to look at their appropriateness. On the other hand, Anastasi (1982) has described various forms of validity for specific measures.

5.2 The goal of the evaluation

The approach adopted in the present evaluation does not fall neatly into one of House's categories. Paradoxically, it is a combination of what he terms 'goal-oriented' and 'goal-free' approaches. The former relates to expected outcomes while the latter ignores the goals which, in the present case, the aid designer had in mind. The paradox arises because the dichotomy which House proposes is a false one; it is difficult to see how a truly goal-free evaluation could take place, as there must be some basis for selection of the measures. Goal-free is a misnomer. A better distinction would be between goal-oriented evaluations in which the designer's aims are being explicitly measured and those for which the evaluator is supplying his own aims.

The purpose of the present evaluation is to assess the quality of a given mobility performance. There is not necessarily an ideal against which a particular performance is being compared, merely a comparison between two conditions. For example, the performance of a long cane user compared with the same pedestrian's performance when using another aid in conjunction with the long cane. The assumption is that a good mobility aid or technique will improve the quality of the mobility of blind people. A further implicit assumption is that an improvement in quality of mobility should be reflected in an improvement in quantity, but only the quality of mobility is tested in the evaluation. (The reasons for this approach are discussed more thoroughly below.)

A number of the goals of the evaluation are related to the performance of a cane user. However, they are partly divorced from the aims which Mobility Officers have when they teach mobility, for the evaluation is not so much interested in technique as in the result of that technique. Thus, although measures such as cane contacts with shorelines and mean pavement position are taken, those such as size of cane arc and coordination of step with cane swing are not. The inclusion of the former measures shows that there is an explicit realisation that a specific performance is not being judged by the criteria of sighted mobility. Although many of the measures are derived from the use of the long cane, other measures such as pavement variability, body contacts, and the spoken commentary are less aid specific.

House(op cit.) makes a further distinction between objectivist and subjectivist approaches to evaluation. The former refers to the technique by which objective measures are taken and the latter to occasions when an opinion is sought. Kay (1980) has argued that the only way to assess what he terms 'enhancement' of mobility is to ask O & M specialists (Mobility Officers) for their 'experienced judgements'. However, he admits that when he tried this approach to evaluate one of his own aids, the experienced judgements which he received were 'unbelievably unreliable'. He implies that this resulted from the Mobility Officers not being 'sufficiently secure in their positions'. This illustrates one problem with the subjectivist approach and almost suggests that a measure is needed of how experienced and secure are the people whose judgements are to be sought; this could result in an infinite regression!

Nunnally and Wilson (1975) have pointed out further reasons for choosing the objectivist approach. Measurement provides a finer scale than subjective judgement. This will allow statistically based decisions to be made about an aid's worth. Although non-parametric statistics could be applied to a coarse measure - e.g. the aid improves/does not improve mobility - there would be a need for a larger sample if a potentially useful aid were not to be unfairly disregarded. In addition, certain measures can only reliably be assessed objectively. This is particularly true when judging speed, as there is a need to allow for time spent not walking.

Thus, the evaluation can be described as objective and as designed to test goals which the evaluator has supplied.

5.3 The validity of the measures

Anastasi (op cit.) while describing the types of validity which an evaluation tool should possess, points out that they are not neatly distinguishable. However, there is a need to introduce the concepts more thoroughly and this can most clearly be done by a short discussion of the terms, followed by a more general discussion of their relevance to the present case.

Construct validity refers to the problem of ascertaining whether the assessment procedure actually measures the theoretical construct which it was designed to test. Criterion validity refers to the need for external confirmation that the assessment can predict how an individual should perform under certain circumstances. The criteria can be of two types: concurrent, which refers to the person's present abilities; and predictive, which refers to some future ability. Content validity deals with the question of how representative are the specific measures which were chosen to be included in the assessment battery. Finally, face validity refers to the need for the person taking part in the evaluation to perceive it as a relevant exercise and worthy of their efforts. (House - op cit. - refers to another form of face validity. He notes that there is a need for the intended audience of the assessment's findings to perceive the procedure as relevant, and thus worthy of being used as a basis for taking decisions. This is a complex political matter which will not be dealt with in this thesis.)

5.3.1 Concurrent and face validity

Neither concurrent validity nor the face validity to which Anastasi refers present a problem for the assessment technique, because the assessment tool embodies the skill about which information is required, rather than being an abstraction from it. The evaluation is carried out in the real world, using the kind of route which a blind pedestrian is likely to want to attempt. However, the specific choice of measures has obviously to be defended.

5.3.2 Construct and content validity

In the present case the theoretical construct is mobility. The choice has been made to restrict the range of the evaluation. Leonard and Wycherley (1967) included the ability to navigate an unfamiliar environment and the ability to cope with sighted help in their definition of good mobility. The former, while important, is a rarer task than that of coping with a comparatively familiar environment. It could, however, be argued that were an aid to be sufficiently good and widely used such a form of mobility would become more common; when the quality of mobility aids rises to this level then the evaluation package can be modified accordingly.

Armstrong (1975) distinguished three main factors which could be said to determine blind mobility: safety, efficiency and stress. Therefore, a pedestrian might never be in danger, but be highly inefficient and under great stress. The ideal mobility aid or technique would be one which optimized all three factors. There have been a number of attempts to measure stress in blind mobility, but none have been wholly successful - the reasons for this are given in a later chapter. Thus, although stress is still viewed as an important factor the measures have had to concentrate upon safety and efficiency.

5.3.3 Predictive validity

The establishment of predictive criteria would appear, at first glance, to be a simple matter. The assumption, mentioned above, is that an improvement in quality of mobility should produce a concomitant improvement in the quantity of journeys which are made. To test this, there obviously needs to be a follow-up study of those whose mobility has been assessed using the Evaluation Package. However, the interpretation of the results of such a study would be less simple than might be assumed.

The factors which affect the number and type of outings which blind pedestrians make are manifold: included among them are motivation and lifestyle (Clark-Carter, 1984). The pattern of outings which were made prior to the initial evaluation are likely to determine the pattern which follows the evaluation. To expand upon this point: if a blind person has established a particular way of living, has accepted that he is unemployed and does not need to make more than a certain number of outings, then even the restoration of vision might not affect this self-image if others are willing to continue their supportive role. However, had the person been provided with a mobility aid prior to the formation of this self-image, then it might never have formed in this way. Gregory and Wallace (1966) found the opposite effect in the case of a highly competent blind person, who, having lost his sight at around the age of ten months, was given sight some fifty years later. Far from becoming more mobile, this person appeared to lose his confidence.

Thus, with the small numbers used in the evaluation, such a follow-up would be of limited value. The only effective way to assess the longer term value of a mobility aid would be to supply the aid more widely and to conduct a survey of mobility habits among the wider sample, while including questions which are designed to ascertain whether factors other than the aid's quality can account for any individual's lack of increased mobility.

Woolf (personal communication) has proposed that a simple and possibly more effective measure of an aid's worth would be the number of this larger sample who continue to use the aid after a given interval. It is true that providing the aid to a larger sample for an extended period will answer important questions about the mechanical reliability of the aid. However, to answer the wider question it would be necessary to monitor regularly whether aids continued to be used appropriately; in other words, mini objective evaluations would have to be conducted.

5.4 Conclusions

Potential aid users will differ as to the benefits they require from an aid. One person may want greater safety but be willing to accept a reduction in speed, while another may want greater speed and be willing to take an increased risk. Thus, unless the aid produces a resounding improvement in all aspects of mobility, the evaluator is limited to reporting relative improvements in the specific areas of safety, efficiency and, possibly, stress.

The present evaluation is designed to assess such improvements in the shorter term. It does not assess the longer term effects of any improvement.

The next two chapters report evaluations which applied the procedures which have been described thus far. The first deals with an evaluation of the self-trained users of the guide cane, and the second with an evaluation of the Sonic Pathfinder.

Chapter VI

The mobility of self-trained cane users

6.1 Introduction

The self-taught guide cane users who were identified in the Nottingham Survey were of particular interest: why had they not received mobility training, how safe and efficient was their mobility compared with those who had received training and, particularly, had they developed any useful strategies which were not being taught by mobility officers? From the information collected at the time of the survey these questions could not be answered; the questions about mobility which had been asked dealt with more general aspects, such as the number of outings made in a normal week.

6.2 Procedure

To find out why these cane users had not received mobility training was a simple matter of asking them; to this end a short questionnaire was compiled which also asked about registration, mobility, vision, additional disabilities, employment and willingness to take part in an evaluation (see Appendix III). To assess their skill at mobility and to relate it to the skill of those trained with the long cane it was necessary to have some of them take part in the standard evaluation procedure.

6.3 Subjects

It was decided to limit the investigation to those aged below seventy years as they were likely to be more mobile and would be a fairer comparison with the long cane users, who were also all under seventy years of age. Subjects were contacted initially by letter. From the return of letters, and subsequently from visits to subjects' homes, it was possible to discount those subjects who were never in when visited, were too ill, had moved from Nottingham, had died or had been de-registered. The potential sample was reduced to twelve people who were successfully interviewed. From them five were selected for a more thorough evaluation of their mobility, on the grounds that they were willing to help and professed to have good mobility.

6.4 The Questionnaire

All those interviewed were registered as blind; Tables 6.1 and 6.2 show their vision, the number of outings they made in a normal week, whether their mobility was fully evaluated and, where applicable, the reasons why they did not take part in the full evaluation.

Can see	Number of outings made in a week	Reason for not taking part in the full evaluation
Nothing	3 - 4	Too ill
presence of light	7 +	Did not want to
presence of light	1	Too ill
presence of light	1 - 5	Too ill
Bus at 3 Metres	1	Mobility too restricted
Car at 3 Metres	10	Too ill
Bicycle at 3 Metres	2	Wife objected

Table 6.1: The self-trained guide cane users whose mobility was not fully assessed: their vision, number of outings made in a week, and reasons for not taking part in the full evaluation.

Subject no.	Can see	Number of outings made in a week
1	Bicycle at 3 Metres	5 - 6
2	Nothing	7 - 8
3	Bus at 3 Metres	11 - 20
4	Bicycle at 3 Metres	6 - 10
5	Bicycle at 3 metres	11 - 20

Table 6.2: The vision and number of outings made in a normal week by the self-trained guide cane users who took part in the full evaluation

6.5 Reasons for not receiving training

Table 6.3 shows the reasons which subjects gave for not having received tuition in mobility and relates this to their level of vision. Only one person had not previously heard of Mobility

Officers. This result is probably not representative of other parts of the country as, while taking part in the original survey, they were made aware of the existence of Mobility Officers. Over fifty percent did not feel the need for mobility training, either because they were confident in their own technique or because they felt they had adequate vision.

	Vision				
	Totally Blind	Perceives light	Bus at at 3 m.	Car at at 3 m.	Bicycle at 3 m.
Adequate vision			1	2*	1*
always accompanied	1				
Never heard of M.O.s		1			
Confident in own technique	1*	1	1*		
Too old					1
Too infrequent or restricted journeys		1	1		

*Mobility subsequently evaluated.

Table 6.3 - The vision and reasons for not having received mobility training of self-trained guide cane users.

6.6 Evaluation of Mobility

Six totally blind long cane users took part in the evaluation of the Sonic Pathfinder, which is described in the next chapter. These subjects were usable as a control group for the present study, allowing comparison between conventionally trained cane users and the untrained group. In order to make a fair comparison between their performances, the five subjects in the present study who underwent the complete evaluation walked the test route three times. A video recording of their performance and an audio recording of a simultaneous commentary which each made were taken on each of the passes, with the intention that only the last pass was to be compared with the performance of the long cane users.

During the filming of the self-trained guide cane users it became evident that three of them had considerable guiding vision, and thus it would be unreasonable to make an overall comparison between the entire present sample and the sample of long cane users. For this reason each subject is described individually before any analysis is reported.

Subject One had vision in only one eye which suffered from macular degeneration. He made up to six journeys in a normal week. His performance was that of a sighted person and he was able to comment, on the basis of visual information, about a junction two metres before he reached it. Thus he could see further than his cane could reach.

Subject Five suffered from optic nerve atrophy. He could see as far as subject one and was able to comment on, at two metres, and avoid, using sight, obstacles such as wheel barrows. He also travelled as though sighted.

Subject Four was totally blind in one eye and had retinal degeneration in the other. Although he walked very slowly - taking over thirty percent longer to travel the route than those trained with the long cane - he used the cane as though he had been trained. On further questioning he admitted that while he had never been trained formally, someone had shown him how to use the cane and he had obviously discussed the technique with users of the long cane. Nonetheless, he had sufficient sight to see the presence of trees at two metres and could even describe the composition of walls at one metre.

Most interesting for this study were the two remaining subjects. Subject Two was totally blind and most frequently travelled with a guide dog, but often he used the guide cane on its own. Subject Three probably suffered from retinitis pigmentosa as he had many of the symptoms, including reduced visual field. The visual condition of these two subjects meant that their performances on the test route could reasonably be compared with those of the long cane users.

The standard evaluation which both groups underwent involves measures of safety and of efficiency. Among the former are counts of the number of times they come into bodily contact with obstacles or walls, and whether they stray into the road or fall off the pavement. Among the efficiency measures are the ratio of the time on the route to the time spent walking, and the straightness of the path they take.

Both subjects Two and Three had independently developed a similar technique with the cane. They held it in the hand nearest the inner shore line (ISL) and frequently contacted the ISL; they produced significantly more cane contacts with the ISL than did the users of the long cane (see Table 6.4). In addition, the guide cane users tended to hug the inner shore line; they had a mean pavement position of 2.03, while the mean for long cane users was 2.33 (a score of 1 denotes continuous contact with the ISL, 5 continuous contact with the outer shore line and 3 a mid-pavement position). Neither used the cane to check that the way ahead was safe; Subject Two produced five major safety errors - though this was within the range of the long cane users. Their productive walking index (0.93) was only slightly below that of the long cane users (0.96).

	Long cane users n = 6 mean	Guide cane users n = 2 mean	t	probability (2-tailed)
Walking time	6.27	5.43	1.03	0.340
Productive walking Index	0.96	0.93	1.19	0.275
Cane Contacts with inner shore line	50.5	214.5	2.49	0.048
Cane contacts with outer shore line	19.0	5.5	1.56	0.165
Cane contacts with obstacles	8.8	9.0	0.07	>0.9
Body contacts with ISL	4.3	3.5	0.33	0.745
Major safety errors	2.7	2.5	0.07	>0.9

Table 6.4 - Measures taken of the mobility performance of those trained with the long cane and those who have devised their own technique with the guide cane.

6.7 Verbal Commentary

Two separate analyses were conducted of the types of utterance made during the verbal commentaries. Firstly, the two guide cane users who had the poorest vision were compared with the long cane users (see Table 6.5). Secondly, the three guide cane users with better vision were compared with the long cane users (see Table 6.6).

Type of utterance	Long cane (n = 6) mean	Guide cane (n = 2) mean	t	probability (2-tailed test)
Surfaces	8.67	1.5	1.51	0.180
Obstacles	7.5	7.5	0.00	>0.9
Shorelines	10.67	5.0	0.62	0.550
Sounds	6.00	4.0	0.93	0.385
Mobility technique	41.33	9.0	3.49	0.013
Hypothesis statement	6.83	8.5	0.76	0.470
Hypothesis dis/con firmation	2.83	4.5	1.28	0.245

Table 6.5: A comparison between long cane and self-trained guide cane users: verbal commentary.

Type of utterance	Long cane (n = 6) mean	Guide cane (n = 3) mean	t	probability (2-tailed test)
Surfaces	8.67	4.33	1.06	0.315
Obstacles	7.5	11.00	0.98	0.350
Shorelines	10.67	20.67	1.24	0.249
Sounds	6.00	1.67	2.48	0.041
Mobility technique	41.33	6.67	4.74	0.002
Hypothesis statement	6.83	1.67	3.99	0.005
Hypothesis dis/con firmation	2.83	0.33	2.38	0.048

Table 6.6: A comparison between long cane users and guide cane users who have guiding sight: verbal commentary.

The only significant difference between the long cane users and those who use the guide cane as a mobility aid was that the latter group made fewer comments about mobility technique. This finding is consistent with their not having received mobility training nor the vocabulary to describe the technique; the long cane users employed terms such as 'touch and drag' and 'squaring-off' which they had learned in the course of mobility training.

The guide cane users who had guiding sight differed significantly from the long cane users in a number of respects. Firstly, they commented less on mobility technique. Secondly, they appeared less aware of environmental sounds. Thirdly, they made fewer statements which suggested that they were entertaining hypotheses about what might be in the environment and fewer statements about whether or not such hypotheses had been confirmed.

These results are consistent with their having received sufficient information through vision not to need to attend to other modalities, and with their being confident that they recognised the objects which they sensed around them. This illustrates the point made earlier in this thesis that mobility for those without guiding sight involves more conscious hypothesis generation and testing than it does for those with vision; even, as is shown here, in some cases where that vision is poor enough to warrant the person being registered as blind.

To check that the group differences in verbal commentary were not due to the long cane users being more loquacious, the number of words employed by each subject in their commentary was noted and a comparison was made between the groups. There was no significant difference between the groups ($t = 0.34$; $p = 0.73$; two-tailed test).

6.8 Conclusions

6.8.1 The need for training

The users of the guide cane who have not been trained in mobility can be divided into two groups. Firstly, those who correctly think that they have sufficient vision not to need training. If they need to carry a cane at all it is merely to symbolize their impairment in order to prevent misunderstandings with the sighted population. The second group, those with poor acuity or reduced visual field, could probably benefit enormously from mobility training. Their technique is likely to leave them totally unprotected against obstacles in their path and to give them little warning about changes in pavement texture, continuity and gradient.

Subject Four showed that a small amount of advice about how to use the cane can be extremely beneficial to a client's safety, although his efficiency, in terms of speed, could have been improved by longer training. If mobility officers could be informed about who was acquiring guide canes, then they would probably need to spend no more than about an hour with such a person to give them a rudimentary knowledge of cane technique. In the City of Nottingham approximately sixty-five people use a cane and yet are untrained in its use, and of them just under fifty percent have poor enough vision to warrant some training. There is no reason to regard these proportions as atypical. Therefore, Mobility Officers should be able to advise all such clients in their area, without too great an increase in their workload. More importantly, this might prevent many visually impaired people having to wait years before they receive mobility training.

6.8.2 The Evaluation Package

This study has proved useful in identifying shortcomings in the evaluation procedure. The Standard Evaluation Package was designed to assess the mobility of those with a severe visual impairment. For those with guiding sight, most of the measures were inappropriate. In order to direct attention to the problems of the partially sighted, different measures will be needed. The verbal commentary will provide one such measure but its scoring will need to be modified to take account of the reports which subjects give of visually acquired information. Later in the thesis a new measure - Percentage of Preferred Walking Speed - is proposed.

Chapter VII

The Evaluation of the Sonic Pathfinder

7.1 Subjects

Five males and one female took part in the evaluation. Apart from one male all were late blinded, and apart from the female, who had some perception of light, all were totally blind. All but one of them were contacted via their Mobility Officers. The exception was a male who had contacted the Unit himself. Their ages ranged between 21 and 65 years and all would be considered highly mobile. All were regular long-cane users, though one also used a guide dog.

7.2 Training

It had been assumed that the display of the aid was sufficiently self-explanatory that little training was needed in its use. Accordingly, subjects were not trained to any agreed criteria. One was self-trained, one was trained on an ad hoc basis by the aid's designer and the rest were trained by Mobility Officers. Only one of the Mobility Officers had received formal instruction with electronic mobility aids, and he gave his client the complete course which was designed for users of the Sonic Guide.

7.3 Procedure

Each subject had the route described to them, and the sample commentary was played to them. Each subject then walked the route three times: once to familiarise themselves with the route and the task of producing a commentary, secondly with the long cane and Sonic Pathfinder, thirdly only using the long cane; they wore the Pathfinder throughout but it was switched off during the first and third passes of the route. Video and audio recordings were made of each pass of the route.

7.4 Results

7.4.1 Mobility measures

A comparison was made, using related t-tests, of the second (Pathfinder and cane) and third (cane only) passes of the route. The seven behavioural measures are shown in Table 7.1. On only two measures was there a difference between the two conditions which was close to significance at the five percent level: cane contacts with obstacles and body contacts with the inner shore-line. In both cases the pass in which the Pathfinder was used produced the lower score. In addition, fewer cane contacts were made with the inner shore-line and more cane contacts were made with the outer shore-line when the Pathfinder was used.

Measure	Condition			
	Pathfinder + cane	cane		
Walking	mean	mean	t	probability (2-tailed test)
time	6.43	6.27	0.49	0.645
Productive index	0.947	0.964	1.00	0.355
Cane contacts isl	12.667	50.500	1.74	0.145
Cane contacts osl	26.167	19.000	1.69	0.155
Cane contacts obstacles	6.333	8.833	2.05	0.098
Body contacts isl	1.167	4.333	2.61	0.047
Major safety errors	1.833	2.667	0.70	0.515

Table 7.1: Comparison between use of the Sonic Pathfinder with the long cane and the long cane alone: behavioural measures.

7.4.2 Pavement Position

Mean pavement position was significantly higher (i.e. nearer the outer shore-line) when the Pathfinder was in use but there was no difference in the variability of pavement position (as expressed by standard deviation) between the conditions (see Table 7.2).

	Pathfinder + cane	Cane	t	probability (2-tailed test)
Mean	2.61	2.32	2.65	0.045
SD	0.75	0.76	0.25	0.815

Table 7.2 Pavement position: a comparison between Pathfinder plus long cane and cane alone.

7.4.3 Verbal Commentary

Of the seven measures taken from the verbal commentary there were significantly fewer comments about environmental sounds and more comments about obstacles and hypotheses when the Pathfinder was in use, and a tendency for fewer statements to be made about surfaces (see Table 7.3).

Measure	Condition			
	Pathfinder + cane	cane		
	mean	mean	t	probability (2-tailed test)
Surfaces	5.17	8.67	1.72	0.145
Obstacles	14.83	7.5	4.29	0.008
Shorelines	12.33	10.67	0.76	0.475
Sounds	2.17	6.00	3.89	0.012
Mobility technique	35.17	41.33	1.19	0.275
Hypothesis statement	9.83	6.83	2.92	0.015
Hypothesis dis/con-firmation	3.33	2.83	0.62	0.550

Table 7.3: A comparison between Pathfinder plus long cane and cane alone: verbal commentary.

7.5 Discussion

All the results can be explained by the fact that when using the Pathfinder pedestrians were able to move further from the ISL. Hence they did not contact the ISL as frequently with either cane or body yet did make more cane contacts with the OSL. In addition, when using the Pathfinder they had greater warning of obstacles and so hypothesised more about the nature of those obstacles but contacted fewer of them. There was evidence that the output of the Pathfinder masked environmental sounds, or at least distracted attention from them.

Putting these findings in the framework of Safety and Efficiency, the reduction in body contacts with both obstacles and the ISL when using the Pathfinder is a mark of greater safety, however, there was no evidence of increased efficiency with the aid. As for enhanced awareness of their environment they were more aware of the presence of obstacles but less aware of environmental sounds. In short, the aid showed an improvement on some measures but not a dramatic overall improvement.

The function of the evaluation is to assess the worth of a finished package - be it an electronic aid or a training technique. As it is both labour intensive and time consuming its use on an evolving package is very inefficient, for two reasons. Firstly, while the evaluation may show that a product fails to fulfil its promise, it will not show why this is the case or how to improve the situation (Heyes, in press). Secondly, and more importantly, it is not the ideal way to assist the design of an aid.

Engineers have traditionally arrived at their designs for mobility aids a priori. Heyes (in press, op cit) has, for this purpose, proposed the use of 'introspection'. By this he means that the aid developer should literally put himself into the position of the blind pedestrian; he should wear the aid, and ask himself, when a specific problem is encountered on a route, what information the aid could provide which would solve this problem. Since the evaluation of the Pathfinder he has used this technique to arrive at modifications of the aid (Heyes, 1984b).

Leonard (1971) took a two-pronged approach to the design of aids. Firstly, he analyzed the role of vision in mobility and looked at how the essential information which is normally supplied by vision could be presented to the remaining senses. Secondly, he observed blind pedestrians who were considered to be good travellers, to see how they coped and to see what information might further improve their mobility.

The approaches adopted by Heyes and by Leonard are certainly preferable to that adopted by engineers, but it should be recognised that all three are alternative means of arriving at hypotheses. As hypotheses they need testing and refining, and the evaluation package is not the tool for this purpose. Between the generation of the hypothesis and the full evaluation of its implementation there needs to be another stage. This should include psychophysical tests of specific modifications. In this way aspects of the modification can be altered and compared, and the best version can be arrived at before being incorporated in the final aid. Only then should the aid be subjected to a full evaluation.

A follow-up to the evaluation emphasises the point that predictive validity is difficult to adduce in this context. Only two of the original six participants have continued to use the aid. However, one person is seriously ill, one has chosen to use a guide dog, and two have ceased to use it because their aids developed faults. Thus, only one person has a perfectly sound aid and yet has chosen not to use it, and they have not returned to the long cane alone, but have chosen an alternative aid.

7.6 Conclusions

Existing parameters of the Pathfinder should be assessed according to the intermediate principle described above, before it undergoes another full evaluation.

The evaluation package still lacks a measure of stress. The subject who has chosen to use a dog, like many others who have made this choice, gives as her reason the relative lack of stress which she experiences when she uses a guide dog. The next two chapters review work on the nature of stress and the attempts to measure it in blind mobility. A later chapter investigates the mobility of guide dog users.

Chapter VIII

Stress

8.1 The concept of stress

Mason (1975), referring to work on stress, states that 'the general picture in the field can still only be described as one of confusion.' Both he and Cox (1978) identify three ways in which stress is described. The first is most famously identified with the work of Hans Selye and treats stress as a response to stimuli. Selye terms it 'the non-specific response of the body to any demand' (Selye, 1979) which sounds somewhat all-embracing. In fact he means that the response is basically the same regardless of the stimulus and that stress can only be said to be present when that response occurs.

The second approach sees stress as residing in the stimulus and is the one which Cox believes is most similar to the usage that lay people, and thus dictionaries, employ. This seems simply to be a relabelling of the term 'stressor' as used by those adopting the first approach to describe the cause of stress. However, Sanders (1983) sees a certain advantage in the second approach in that a distinction can be made between arousal and stress, which he believes cannot be made using the first definition; arousal will be discussed later in this chapter.

The third approach - the one which Cox favours - avoids the conflict between the other two by defining stress as being involved in the whole situation, as an interaction between the environment and the person. Sanders argues that this is more representative of the lay person's understanding of the term as it takes account of the person's subjective assessment of their ability to cope with given demands. He defines stress as 'a state of unacceptable divergences between perceived demands and capabilities to adapt'. While this definition covers the aversive connotations sometimes implied when stress is referred to, it seems to miss an aspect which is present for the blind during mobility as well as in other cases where stress is experienced. Namely, the knowledge that one can cope with the situation, probably quite adequately, but that, nonetheless, the demands made can take their toll. For example, Glass and Singer (1972), using unpredictable noise as the creator of stress, found that although subjects adapted to the noise, as shown by measures of skin conductance and by performance of cognitive tasks such as number comparison and addition, there was an after effect which impaired subsequent performance on tasks such as proof-reading when the noise was no longer present.

Sanders' definition is too narrow. There are situations where one would want to talk of stress when the person under investigation does not experience the situation as aversive; for example, when the stress involves noise levels at a discotheque, the intake of alcohol, or the effort involved in a sport.

Rather than try to provide a definition which accounts for all types of stress it would be more appropriate in this thesis to follow Levi's advice that one should make clear to which of the many stress concepts one is referring (Levi, 1971).

For the purposes of this thesis stress will be assumed to be present for the visually impaired during mobility because being independently mobile requires levels of vigilance and information processing which are close to, or beyond the limit of, their capabilities. This will mean that their safety could be in jeopardy, or their efficiency impaired, from any additional demand, or that their performance on tasks which they undertake after they have walked may be impaired.

8.2 Arousal

Arousal is sometimes used interchangeably with stress, especially when stress is used in the first sense mentioned above - as a form of reaction. Cox (1978) distinguishes between the two concepts, pointing out that whether a particular level of arousal is experienced as stressful depends on the context. Thus, high arousal can be a sign of excitement or of anxiety, while low arousal can be a sign of relaxation or of boredom.

8.3 The effects of stress

The effects of stress can be expressed in a number of ways depending on the level of analysis adopted: biochemical, physiological, behavioural, or psychological. Some researchers argue that stress is a unitary concept and that therefore, regardless of the situation, if stress is present an individual will show a particular pattern of reaction (e.g. Selye, 1983). Others claim that the reaction will vary according to the specific situation and that consequently there is a poor correlation between different measures, such as heart rate and galvanic skin response, which are frequently used to assess the presence of stress (e.g. Lacey, 1967). For the purposes of the present thesis an exhaustive discussion of each level of measurement would be otiose as behavioural and psychological effects are of primary interest. However, as such measures are frequently used in research to demonstrate the presence of stress, a brief discussion of their relative merits for the present study is given later.

Since the publication of a review paper by Easterbrook (1959) there has been a growing body of evidence that stress has particular effects upon attention. With increased levels of some types of stress there is a narrowing of attention, such that subjects concentrate more on aspects of the task which are of central importance, to the detriment of peripheral aspects. Hockey (1979) reports that stress induced by noise (100 dBA) improves a tracking task while decreasing the likelihood that the onset of lights in peripheral vision will be detected. Yet, although stress induced by sleep loss produces a general decrement in both tracking and light detection, tracking was the more impaired.

The interpretation which Hockey places on his finding with respect to noise is disputed by Poulton (1978), and an attempted replication by Forster and Grierson (1978) failed to produce the same results. However, as Hockey (1978) pointed out, the noise level used by Forster and Grierson was lower than the level which he used.

Nonetheless, Hockey notes that both threat and shock have similar effects to that of noise. Thus, when stress involves increased arousal, as is likely in the case of independent mobility for the blind, one can expect a narrowing of attention.

Mobility for the blind differs from the controlled laboratory-based experiment in that numerous aspects of the situation are relevant to the task; as mentioned earlier, hearing, touch and proprioception all inform the blind pedestrian about their progress. If stress narrows attention during this task much which is relevant will be ignored, as there is no obvious dichotomy between central and peripheral stimuli. Hockey (1979) notes that subjects in laboratory experiments, once they are aware of the relative probabilities of occurrence of stimuli, will allot priority to the more likely events. During mobility such allocation of priorities is a far more complex business, particularly when the route is unfamiliar.

8.4 The measurement of stress

One form of analysis which is believed to be a good indicator of the presence of stress relies on the measurement of changes in circulating levels of hormones. For practical reasons when humans are acting as subjects this generally entails taking daily urine samples and observing such changes over a number of days. It is therefore not a useful measure of moment-to-moment changes in stress and, for this reason, events which are more amenable to being recorded peripherally, such as heart rate, have tended to be adopted by researchers for this purpose.

Although there is a poor correlation between measures of stress, researchers often only apply one measure in any one study. This approach is legitimate if there is reason to believe that the changes which are observed in that measure relate to the presence of stress. However, it begs the question about whether the stress produced under one experimental condition is the same as that found under another.

Behavioural measures of stress can take at least two forms. One approach is to look for changes in subjects' performance of the primary task under investigation. In fact, some researchers have argued that a decrement in performance is necessary before stress can be considered to be present (e.g. Berkun et al, 1962). In the absence of a demonstration that there is a relationship between performance and an accepted measure of stress this approach is circular as the researcher is arguing that stress is affecting performance and that the evidence for this assertion is the demonstration that performance is affected. In addition, as argued above, the lack of any decrement in the main task is not evidence that stress is not present but merely that if it is present it is not affecting performance of the specific task under investigation; it may have an effect on a subsequent task, as demonstrated by Glass and Singer (1972).

A second behavioural measure involves the notion that humans have a limited capacity to deal with incoming information. By requiring subjects to perform a secondary task in addition to the primary one, stress will be demonstrated by decrement in the secondary task performance.

Peake (1972), in a study of stress in blind mobility, reviewed various measures to see whether they could be used for this purpose. She dismissed the two types of behavioural measure. Firstly, she felt that the measures of mobility which existed at the time were insufficiently objective. Secondly, she thought that a secondary task would interfere with mobility, either because by its very nature it would compete with mobility - for instance, if stimuli which had to be reacted to were presented as sounds this might mask auditory information useful to mobility - or because, since mobility is self-paced, it could be modified in such a way as to lessen the effect of stress upon the secondary task.

Peake also considered various physiological measures. While she noted that electro-encephalographs (EEGs) could then be taken from a freely moving subject she felt that this technique was not tenable as interpretation of the graphs involved a high level of training. (Stern et al (1980) have since pointed out that EEG recordings are subject to interference from electrical sources, including other physiological events.) Peake dismissed the recording of electro dermal activity, such as galvanic skin response, as it is affected by ambient temperature. She finally decided that heart rate was the most practical measure: the means of recording it is comparatively unobtrusive and would not affect mobility; the information can easily be telemetered and interpreted; and also, as long as physical effort is not confounded with psychological effects, then it is widely accepted as a measure of stress.

Chapter IX

Attempts to measure stress in Mobility

9.1 Heart rate

Wycherley and Nicklin (1970) were the first to investigate the effect of mobility upon the heart rate of blind pedestrians. To monitor heart rate, the output from two small chest mounted electrodes was plugged into a small transmitter which subjects carried in a back pack. The information was telemetered and recorded on one channel of an audio tape, on the other channel of which was recorded a commentary, made by the experimenter, of the subject's progress through the route. In addition, prior to the experiment, a base heart rate level was established over a twenty-four hour period.

Equal numbers of blind and sighted subjects, paired on the basis of age, sex, weight and occupation, took part in the experiment; there was no significant difference in base heart rate between the groups. During the experiment heart rate was calculated for three separate periods: during the two minutes prior to walking the route, while the subject sat in a car; during the entire time spent walking the route; and during the first five minutes after completion of the route, when the subject was once more seated in a car. After being guided once round the route, which was previously unknown to the subjects, each subject walked the route alone on five consecutive days at the same time of day.

Wycherley and Nicklin found that heart rate for the two minutes prior to walking did not differ from the base level and thus did not differ between the groups. However, the blind had a significantly higher heart rate both while walking ($p=0.0002$) and during the subsequent five minutes ($p=0.05$) than did the sighted; although, this was only true when each pass of the route was treated separately. Both groups showed a gradual lowering of heart rate as they became more familiar with the route; Wycherley and Nicklin reported that this effect reduced any difference between the group means.

They included the mean heart rates for each subject under each condition in their paper and it is therefore possible to calculate certain statistics. Related t-tests, used as the subjects were matched, on the means of the five passes of the route show that the blind subjects had higher heart rates during walking than the sighted ($t = 2.862$, $p = 0.018$, two-tailed test) but not during the previous two minutes ($t = 0.959$, $p = 0.35$, two-tailed test) nor during the subsequent five minutes ($t = 1.735$, $p = 0.11$, two-tailed test); Wycherley and Nicklin used Sign tests to compare these means. They argue that as both groups showed similar recovery rates during the five minutes resting period they must have been of equal physical fitness, and that therefore the difference between their rates during walking (sighted mean = 112 b.p.m., blind mean = 132 b.p.m.) is due to the greater stress involved for the blind.

In this experiment there were large individual differences in heart rate which were probably dependent on physical fitness, and the matching was by no means perfect. In one pair the sighted subject had a higher mean heart rate while walking than did the corresponding blind person; the sighted person was the heavier by seventeen pounds and the elder by seven years. If the assumption of matching is ignored and an unrelated t-test is performed comparing the mean heart rate, while walking, of the two groups, then significance is not reached at the 0.05 level ($t = 1.83$, $p = 0.099$, two-tailed test).

Peake and Leonard (1971) used a similar experimental design to that employed by Wycherley and Nicklin, and many of the original subjects. However, to control for physical fitness they also recorded the heart rate of each subject while guided over five passes of the route, but walking at the same pace as they had adopted when walking independently. In this way they were able to establish a base level which involved physical effort while minimizing stress.

There was no significant difference between the heart rates of the blind and sighted groups during any of the three periods when subjects were guided.

However, during each period the blind subjects' heart rates were significantly lower when guided than when walking alone ($p = 0.025$ for each period).

Peake and Leonard (op cit) next tested the effect of route familiarity upon heart rate by having subjects walk both guided and unguided over a familiar and an unfamiliar route. They found that blind pedestrians, trained and experienced with the long cane, had lower heart rates when guided over a route which was familiar to them than when walking alone over the same route. However, they found no difference in heart rate between the familiar and unfamiliar routes. In addition, they found no trend of decreasing heart rate over repeated passes of the same route save in the five minute post-walking period.

Peake and Leonard (1971) also tested the effect of route difficulty upon heart rate. They chose as their simple route an unused running track with a well defined kerb, and as a complex route a very busy shopping area with a high density of traffic. Again guided trials had the lowest heart rate for both routes. However, subjects had a lower heart rate on the simple route than on the complex one, both while walking and during the five minutes post walking period but not during the two minutes anticipation period. In addition, they again found no trend of lowering heart rate across consecutive passes of the routes. They accounted for the disparity between this result and that of Wycherley and Nicklin by pointing out that the route which the latter used was of intermediate difficulty and probably had well defined landmarks, while their own routes either had no landmarks or were unpredictable due to the high traffic and pedestrian density.

There is a complication with this argument as Peake and Leonard found no trend of reduced heart rate across trials with their second experiment when they used a route of intermediate difficulty. They attributed the difference between this result and that of Wycherley and Nicklin to the different mobility aids used in the two experiments. They suggested that the long cane users who took part in this experiment were able to gain more information in a shorter time than could the short cane and guide dog users who took part in Wycherley and Nicklin's experiment. However, they admit that their subjects and those used by Wycherley and Nicklin had comparable heart rates, which somewhat undermines their argument. Their subjects only did three passes of the route whereas those taking part in Wycherley and Nicklin's experiment did five passes, and although they report that the trend did not reach significance the graph which they use to illustrate heart rate shows a definite drop between the first and second, and the second and third passes of the route. Therefore, had their subjects completed another two passes of the route a significant trend might have been shown.

In order to look more specifically at the causes of stress as the blind person walks a route, Heyes et al (1976) attempted to investigate moment-to-moment fluctuations in heart rate and their relation to events on a route. This technique had previously been used successfully to demonstrate changes in the stress level experienced by car drivers (Simonson et al, 1968). To confirm that the heart rates of their subjects would similarly react to stressful events during driving, Heyes et al (op cit) chose as subjects experienced drivers who were also skilled in walking while under blindfold.

Thus, if, as a pilot study had suggested, they failed to show any correlation between heart rate and specific events encountered during mobility, this would not be due to having used subjects with unusual reactions to stress.

Each subject performed three tasks: firstly, driving a varied route which involved both busy town areas and fast dual carriageway; secondly, walking a simple route unaided and under blindfold; and thirdly, walking a more complex route unaided and under blindfold. Their progress on each task was recorded on video tape. Overtaking, being overtaken, and approaching crossings and roundabouts were treated as critical events to which heart rate during driving was to be related. Road crossings, and cane and body contacts with obstacles were their equivalent during mobility.

Heart rate changes could be directly observed as being related to critical events during driving. However, during mobility, apart from a slight increase in heart rate when subjects approached road crossings there was no discernible change which could be identified as relating to critical events.

In fact, no noticeable change occurred even when a subject was hit by a cyclist who had been knocked from his bicycle by a sighted pedestrian!

Heyes et al (op cit) did not compare the heart rates of their subjects during the two routes. However, as they report their data, it is possible to perform the analysis. When the comparison is made there is no significant difference in heart rate as a consequence of route difficulty ($t = 0.759$, $p = 0.475$, two-tailed test). Thus, they failed to replicate Peake and Leonard's (1971) finding with respect to heart rate and route complexity.

Heyes et al (op cit) concluded that as heart rate was generally so high during mobility, resulting from a combination of physical and psychological effort, it did not show a noticeable reaction to specific events.

Tanake et al (1981) confirmed the finding that heart rate is higher when blind pedestrians walk unguided than when they are guided. However, they report a correlation between events, such as kerb incidents, and changes in heart rate. But, they provide no statistical evidence for this statement and only present a graph of heart rate over time which shows such general variability that peaks occur frequently when no events are reported as having occurred.

Notwithstanding the disagreements reported above about mobility and heart rate, heart rate would appear to be a measure of general stress level but not a means of identifying the causes of moment-to-moment changes in that level during mobility.

9.2 Secondary task

A different approach to the measurement of stress, in the context of blind mobility, has been to assess the degree of attention required. Shingledecker (1978) made subjects perform a task in addition to the main one of mobility. He reasoned that at moments when the primary task of mobility was most difficult the pedestrian would be forced to concentrate upon it to such an extent that performance on the secondary task would be impaired. As mentioned in the previous chapter, Peake (1972) had decided against the use of this technique because she felt that the secondary task would interfere with mobility. Shingledecker's secondary task was designed to avoid this effect. Subjects wore small vibrators on their wrists and held in one hand a small panel on which was mounted a pair of buttons. At intervals of between two and four seconds a vibrator was activated and the subject had to respond by pressing the key which they had been told related to that vibrator; in other words, it was a simple two-choice reaction time experiment. The order in which the vibrators were activated was randomized as was the inter-stimulus interval. Reaction times and the particular response key which was pressed were recorded.

Shingledecker used three conditions involving indoor routes which simulated outdoor conditions: one in which subjects were familiarized with a route through five practice trials, one on a new route, and one on the same new route but with subjects receiving verbal preview of particular landmarks and turns. Subjects were told that although they were to try to perform as well as possible on both tasks, mobility was of primary importance and thus if either task was to suffer it had to be the secondary one.

Subjects in the preview group were better than those in the other two groups on the primary task in terms of safety and efficiency - as measured by Armstrong's evaluation procedure. With respect to the secondary task there was no difference between the groups in reaction times or in the number of incorrect responses. However, the preview group responded to stimuli on significantly more occasions than did those who walked the new route unaided. Those walking the familiar route made more responses than those on the new route without preview but this did not reach significance at the $p = 0.05$ level ($0.1 > p > 0.05$), and the preview group did not produce significantly more responses than the familiar group ($p > 0.1$).

Shingledecker (1983) subsequently investigated the effect of route complexity upon secondary task performance, while at the same time checking that the need to perform the secondary task did not have an effect upon mobility. This time he used outdoor routes: a simple one, one of medium complexity in a residential area, and one in a busy shopping area. The secondary task was the same as that used in the previous experiment, but the results for secondary task performance were less clear. Three subjects were used and each showed a different effect of greater route complexity: one had longer RTs, one made more errors, and one had longer RTs and made more errors. A composite measure was produced from long RTs and errors which showed a significant impairment with route complexity. Shingledecker reported that on none of the mobility measures was the performance significantly poorer, at the p=0.05 level, when subjects were required to do the secondary task than it was under a control condition when they simply walked the route.

This particular secondary task can therefore be used to ascertain which sections of a route make the greatest demands upon attention, and it will not interfere with the primary task of mobility. There are, however, a number of drawbacks to its acceptance as the measure for future investigation into moment-to-moment changes in stress. The inter-stimulus interval is such that it is not a continuous measure; on average pedestrians travelled

2.5 metres between stimuli on the complex route and over four metres on the simple route. Heyes et al (1976) noted that at points on the route where subjects could be expected to be more stressed their stride length shortened. Shingledecker found that walking speed was the only mobility measure which was detrimentally affected by route complexity. Subjects were thus slowing down the rate at which information was reaching them. Shingledecker's measure therefore may underestimate the stress involved because it only takes note of the decrement in the secondary task and ignores the degree to which subjects modify the primary task. A further problem with the secondary task is that most electronic mobility aids have to be used in conjunction with the long cane. Therefore, if the aid under investigation is a hand held device the subject does not have a free hand with which to respond to the secondary task. An additional practical problem which arose during recent pilot work is that subjects can become sufficiently adept at the secondary task that in order to produce a decrement in performance its difficulty has to be increased.

A possible solution to these problems, rather than introduce a different secondary task, is to look at the aspect of mobility which has been observed to vary with stress: namely, stride length.

9.3 Stride length

There does not exist a satisfactory means of measuring moment-to-moment stride length outside the laboratory. Pedometers merely record the occurrence of a step and give no record of its size; they could only provide an average step length over a route section. Techniques used by the medical profession to assess gait patterns are laboratory based as they rely either upon special walkways which contain sensors or upon subjects wearing special markers and being filmed under controlled lighting conditions.

The next chapter introduces a device which can be used to measure gait patterns in real outdoor environments.

Chapter X

Preliminary investigation of Gait

10.1 Introduction

Before measures of gait can be used to assess the stressful conditions which blind pedestrians are believed to experience, it is necessary to demonstrate that such measures vary consistently under conditions where stress is already known to be present. Ideally, when it is proposed to use a new measure, its performance should be compared with that of an existing measure; in other words, it should be externally validated.

However, this procedure has not been felt to be necessary when previous measures have been used to assess the stress which is thought to be experienced by blind pedestrians. Heart rate is widely used as a measure of stress, and thus, when it was used with blind pedestrians no prior validation procedure was felt to be necessary (Peake, 1972). Similarly, the validity of the secondary task technique was seen to be acceptable when Shingledecker (1978) demonstrated that on routes where more stress was assumed to be present secondary task performance was poorer.

Heart rate did not vary during the passage of a route, and thus was not an appropriate validator. Secondary task, on the other hand, does show intra route variation, and was accordingly chosen for use in the pilot study. In addition, a measure of the psychological after-effects of stress was utilised.

The pilot study was undertaken to test the feasibility of the technique to be employed for the measurement of gait and to choose the specific validation procedure for use with that technique. Throughout this phase a sighted pedestrian, who had undergone formal training in the use of the long cane while blindfolded, acted as a subject.

10.2 The Recording and analysis of gait

The apparatus for recording gait was in two parts; a more thorough technical description of the apparatus and an outline of its evolution are given in Appendix IV. To record the distance travelled, the pedestrian was required to wear a harness which towed a wheel (see Figure 10.1). To record the occurrence of footsteps, foam insoles, which incorporated pressure sensitive electronic switches, were inserted into the subject's shoes. The data from both sources were recorded using a Sony TCS-310 portable stereo cassette recorder.

Analysis of the information from the footswitches and wheel involved the use of computer facilities; a computer program written for this purpose is given in Appendix V. Graphs were produced of both speed and length of stride, which could then be perused to identify moment-to-moment changes in gait. In addition, means and standard deviations were calculated for both measures.

10.3 The Secondary task

The equipment used by Shingledecker (1983) was employed and is described in the previous chapter. The occurrence of each vibration and of each response was converted into four different frequencies (500 Hz and 800 Hz for the two vibrations, 2 KHz and 3.2 KHz for the responses) for recording on audio or video tape; in this case these data were also recorded using a separate Sony TCS-310 portable stereo cassette recorder, with the occurrence of one vibration and the appropriate response to it going to one audio channel.

It was found during the course of the pilot phase, as equipment and techniques were being refined, that the subject showed a marked learning effect with the secondary task. The difficulty of the task had to be increased to maintain an effect of route complexity upon performance. This was achieved by doubling the speed of stimulus presentation, such that the inter-stimulus interval varied randomly between three durations: 1 sec., 1.3 secs. and 2.1 secs.

The analysis of these data involved the same computer facilities as those used with the measures of gait. A computer program already existed which had been written by a colleague specifically to analyse the data from the secondary task. However, modifications to hardware, involving the frequencies utilized for the recording of stimuli and responses, and an increase in the rate of stimulus presentation, required an additional computer program to be written (see Appendix VI) which prepared the data for the existing program.

10.4 The after-effects of stress

Glass and Singer (1972) gave subjects the task of proof-reading passages of text into which deliberate errors had been inserted. Using the number of errors which subjects failed to detect as a measure, they noted that after certain stress conditions (for example, intermittent, unpredictable noise) subjects showed an impairment in proof-reading. In order to reproduce this task, for use with blindfolded sighted subjects, four essays, each approximately 3500 words long, were taken from Huxley (1960). Naturally-occurring typing and printing errors were chosen: missed spaces between words, missed capital letters, missed full-stops, extra letters, missed letters, a capital letter followed by another capital, two letters transposed, and the use of the wrong tense.

A computer program was written to select randomly the line number, the word within a line and the type of error; where possible, allocation of errors was made upon this basis. In the final form the passages were double spaced with approximately ten errors on each page.

10.5 Routes

Previous research had suggested that both the complexity of a route (Peake and Leonard, 1971) and the blind pedestrian's familiarity with a route (Wycherley and Nicklin, 1970) have an effect on subjects' heart rate, and it is likely that route complexity and familiarity interact. Therefore, it was decided, for simplicity, to select routes which varied as a consequence of only one of those factors, namely complexity. Accordingly, three routes were chosen on the basis of their assumed complexity. Route One - the simple route - was a straight stretch of pavement with a good, continuous inner shore line, and no obstacles at all. Route Two - the one of medium difficulty - was also a straight stretch of pavement, but the inner shore line was not continuous, the pavement was narrower and there were obstacles on the outer shore line. Route Three - the complex one - was narrower still, had sections of ill-defined inner shore line, a greater density of obstacles - including some on the inner shore line - two turns and a road crossing.

10.6 Procedure

The subject walked the routes starting with the simplest and ending with the most complex, in order not to complicate the analysis by contamination of possible after-effects from more to less complex routes. After walking each route his blindfold was removed and he proof-read a passage of text for two minutes. To find a base rate of preferred gait when stress was minimized, the subject initially walked the simple route while accompanied by a sighted guide. He was told to set the pace to the level at which he would wish to travel, rather than simply to be led.

The subject was also told that while he was to try to perform optimally on both the primary task of mobility and the secondary task, if he found that there were occasions when he could not cope with both of them then he was to concentrate on his mobility.

Obviously, measures of gait will be affected by the complexity of a route, simply because the more complex the route the more likely blind pedestrians are to contact obstacles or to become disoriented and thus need to slow down or stop in order to reorient; this would not be a consequence of stress. The question is whether or not gait patterns are affected by route complexity during those periods on the route when the pedestrian is not experiencing specific problems such as cane or body contacts.

It was predicted that in response to route complexity both stride length and walking speed would be reduced.

10.7 Results

10.7.1 Gait

Those occasions when the subject was affected by specific events on the route could easily be identified on the graphs of stride length and of walking speed. It is possible to direct one's attention to the portions of the route where smoother progress was made by removing from the analysis strides which were smaller than approximately 1/4 metre - in other words, where the pedestrian was taking paces which were less than the length of one shoe, and thus had, to all intents, stopped.

Having processed the data in this fashion, there was a clear pattern which showed that the more complex the route, the shorter the stride length, both over the entire route (means compared exhaustively using t-tests, $p < 0.0005$, one-tailed test, for each comparison; see Table 10.1a) and over sections where the subject maintained smooth progress ($p < 0.0005$, one-tailed test, for each comparison; see Table 10.1b). The same trend was observed for walking speed: entire route, $p < 0.0005$, one-tailed test, for each comparison (see Table 10.2a); smooth walking, $p < 0.0005$, one-tailed test, for each comparison (see Table 10.2b).

Stride length (metres)

Route	Condition	mean	standard deviation
Simple	Sighted guide	0.972	0.083
Simple	Independent	0.875	0.141
Medium	Independent	0.561	0.263
Complex	Independent	0.344	0.203

Table 10.1a: The mean and standard deviation of the stride length of a blindfolded pedestrian walking over routes of varied complexity.

(Calculated for the entirety of the routes)

		Stride length (metres)	
Route	Condition	mean	standard deviation
Simple	Sighted guide	0.972	0.083
Simple	Independent	0.887	0.108
Medium	Independent	0.654	0.179
Complex	Independent	0.513	0.145

Table 10.1b: The mean and standard deviation of the stride length of a blindfolded pedestrian walking over routes of varied complexity.
(Calculated for parts of each route when paces of greater than 1/4 Metre were taken - see text)

Velocity (metres/sec)

Route	Condition	mean	standard deviation
Simple	Sighted guide	1.815	0.164
Simple	Independent	1.644	0.146
Medium	Independent	0.981	0.408
Complex	Independent	0.597	0.351

Table 10.2a: The mean and standard deviation of the velocity of a blindfolded pedestrian walking over routes of varied complexity.

(Calculated for the entirety of each route)

		Velocity (metres/sec)	
Route	Condition	mean	standard deviation
Simple	Sighted guide	1.815	0.164
Simple	Independent	1.657	0.111
Medium	Independent	1.116	0.230
Complex	Independent	0.864	0.253

Table 10.2b: The mean and standard deviation of the velocity of a blindfolded pedestrian walking over routes of varied complexity.
(Calculated for the parts of each route when paces of greater than 1/4 Metre were taken - see text)

10.7.2 Secondary task

The results from the secondary task were more complicated; there was a definite increase in failure to respond, or to respond correctly, to stimuli on the more complex routes, yet there was no such increase between walking the simple route independently compared with walking the same route while guided (see Table 10.3). However, there was an increase in reaction times between the guided and unguided conditions, but not between the simple and the more complex routes. In short, there appeared to be a trade-off between accuracy and speed of response, with the latter being impaired first. Although reaction times reached a rough ceiling (approximately 0.6 Sec) this was not imposed by the inter-stimulus interval which would have allowed times of over one second before any overlap occurred between reaction to one stimulus and receipt of the next one. After reaching that ceiling further impairment in performance was signalled by failure to respond at all to stimuli; on two occasions during the most complex route four stimuli in a row were ignored.

Route	Condition	Reaction times (msecs) mean	sd	Percentage correct
Simple	Sighted guide	379	111	97.4
Simple	Independent	571	217	100.0
Medium	Independent	527	255	76.3
Complex	Independent	599	327	65.1

Table 10.3: The mean and standard deviation of reaction times, and percentage of correct responses on the secondary task by a blindfolded pedestrian walking over routes of varied complexity.
(taken from the entirety of each route)

Shingledecker (1983) also noted this mixture of effects upon secondary task performance. He produced a single score from a combination of the two measures. To do this he treated all responses with reaction times in excess of three standard deviations above the mean for the base line (when the subject was guided) as errors. If this procedure is followed in the present case then the expected progressive decrement in performance with increased route complexity occurs. These changes are similar to, if smaller than, those for both walking speed and stride length (see Fig 10.2).

However, this similarity is deceptive. As has been pointed out earlier, the more complex a route the greater the likelihood that a blind pedestrian will meet obstacles. When the secondary task performance is analyzed only for those sections where the subject took strides of greater than 1/4 Metre (i.e. when smoother progress was made) the progressive worsening of performance due to route complexity is much less marked (see Fig. 10.2).

10.8 Discussion

It would appear that secondary task has been adopted as a useful measure of stress because previous researchers have failed to notice the extent to which secondary task errors are associated with specific mobility incidents. The present study, involving as it does moment-to-moment analysis, suggests that during incident-free travel secondary task performance is relatively unimpaired. Thus, secondary task appears to be a good measure of route complexity and its consequences upon attention

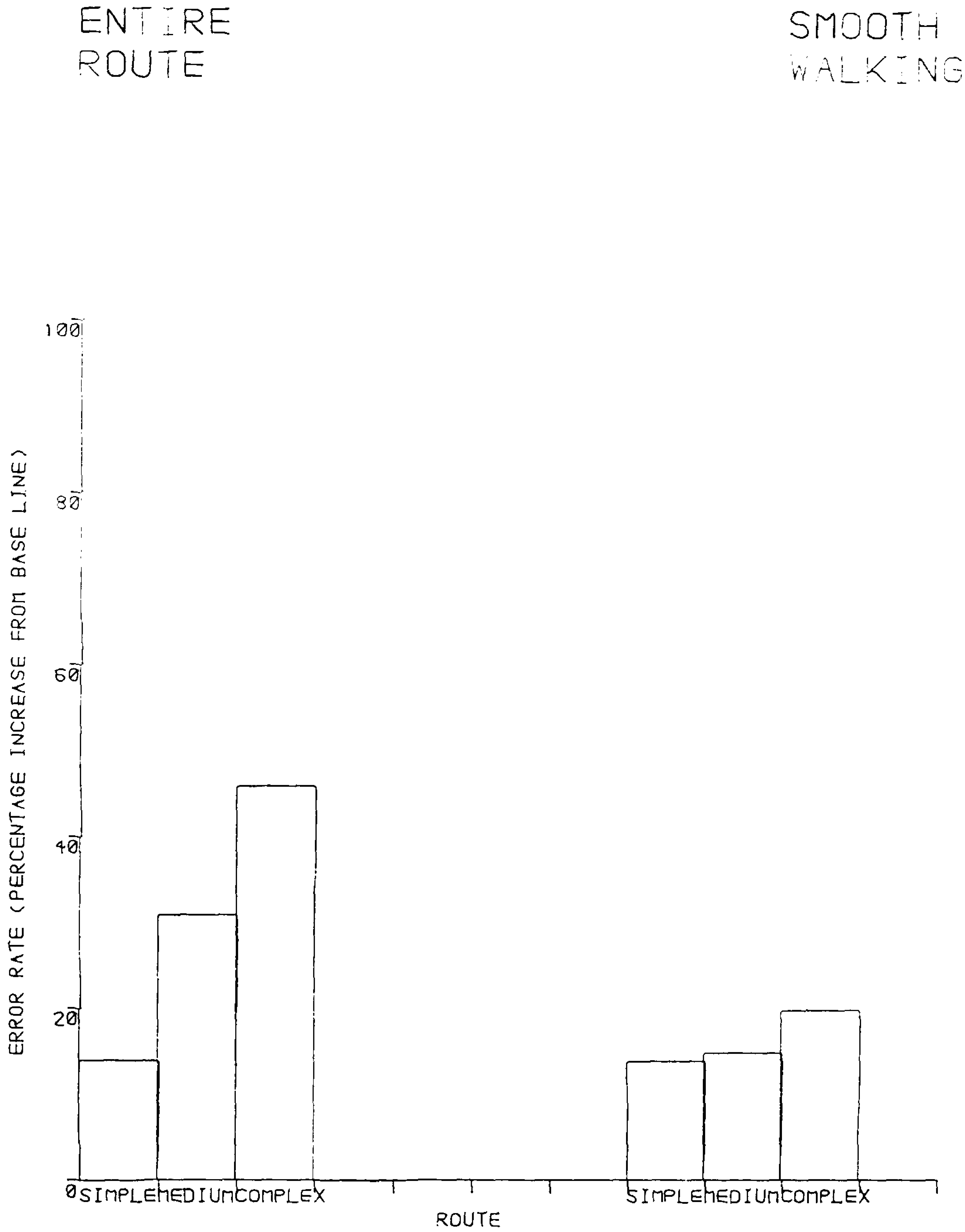

FIG 10.2: PERCENTAGE ERROR RATE ON SECONDARY TASK BY ROUTE DIFFICULTY ENTIRE ROUTE VS SMOOTH WALKING PERIODS

at certain selected points. It does not, however, appear to be such a good measure of the stress which pedestrians are believed to experience during the route as a whole. Gait measures, on the other hand, show both effects. Specific incidents are clearly discernible, but also, in those sections where pedestrians do not encounter such major problems, there is a carry-over caused by the general complexity of a route (see Fig. 10.3).

Scores on the proof-reading task did not correlate with route complexity, though there may have been a slight learning effect between the first and subsequent passages. This suggests that, if stress is involved in this experiment, its type and duration are not comparable with the effects of intermittent unpredictable noise which were noted by Glass and Singer (1972).

Before secondary task can be rejected as a measure of stress (or mental load), in the context of blind mobility, it needs to be investigated more extensively. However, such a task is not appropriate to this thesis as an alternative to the secondary task is being sought here. Given the

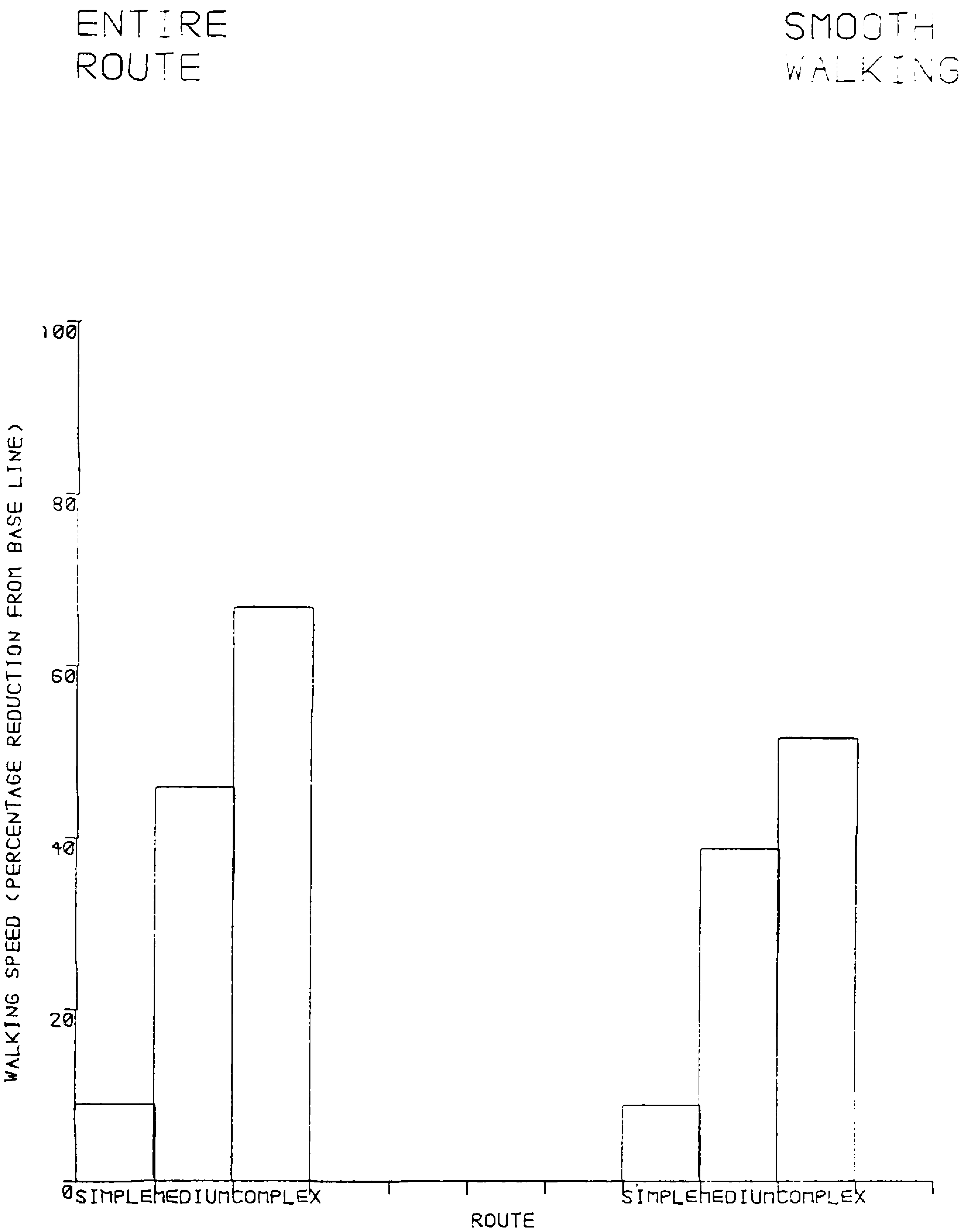

FIG 10.3: PERCENTAGE REDUCTION IN WALKING SPEED BY ROUTE DIFFICULTY ENTIRE ROUTE VS SMOOTH WALKING PERIODS

doubt which has been created by this pilot study it would also not be appropriate to use secondary task or proof-reading as indicators of the presence of stress. Accordingly, The next experiment utilised a different psychological validator - a mood checklist.

Chapter XI

An attempt to validate Gait as an index of Stress

11.1 Introduction

11.2 Design

11.3 Subjects

11.4 Procedure

11.5 Apparatus

11.6 Routes

11.7 Results

  11.7.1 Gait

  11.7.2 Reported Mood

11.8 Discussion

11.1 Introduction

It was necessary to demonstrate that the findings from the pilot study, with respect to gait, were not only replicable but replicable with visually impaired pedestrians. To this end the gait patterns of three visually impaired pedestrians were measured while they walked routes of varying complexity. In addition, another attempt was made to compare gait patterns with an existing stress measure.

11.2 Design

The experiment was to be a repetition of the pilot study, but without either the secondary task or proof-reading. Instead, a mood adjective checklist, the Stress Arousal Check List (SACL, Mackay et al, 1978), was administered on various occasions throughout the experiment to monitor the after-effects of mobility. The SACL requires respondents to rate the degree to which thirty adjectives describe their present mood. Each adjective can be rated on a four point scale: firstly, as definitely describing how they feel; secondly, as only slightly describing their mood; thirdly, as not applicable; and fourthly, as describing the opposite of their present mood. The experimenter read both the instructions and the adjectives, and marked the score sheet for the subjects.

11.3 Subjects

One male and two females, all registered as blind, took part in the experiment. All were trained users of the long cane. Although subjects were aware that stress was being investigated, they were unaware of the specific hypothesis relating gait to route complexity.

11.4 Procedure

Initially, to derive a base line, each subject was guided over the simple route. To enable the measurement of each subject's preferred walking speed they were asked to set the pace. They then walked each of the three routes independently and using a long cane, starting with the simplest and ending with the most complex. On five occasions they had to complete the SACL: once when they arrived in the experimental area and once after each pass of a route.

11.5 Apparatus

Throughout the experiment each subject wore the footswitches, and the harness which towed the wheel. The information from these devices was recorded on the personal stereo recorder which had been used in the pilot study, and each pass of the route was video taped.

11.6 Routes

Subject One walked exactly the same routes as those used in the pilot study. However, between the time the routes had been chosen and the validation experiment, the simple route had become badly encroached upon by brambles, growing from the inner shore line, and covered in a heavy and uneven layer of leaves. The nature of the route was thus radically altered. An alternative was chosen which had the simplicity of the original route, and the remaining subjects completed this alternative as their simple route.

11.7 Results

11.7.1 Gait

The data conformed to the prediction that both stride length and walking speed would be reduced with greater route complexity (Stride length: $F = 19.202$, $df = 3,6$, $p = 0.0019$, see Fig 11.1; Walking speed: $F = 19.955$, $df = 3,6$, $p = 0.0015$, see Fig 11.2).

However, the other factor involved in speed - the time taken to make a stride - also varies with greater route complexity - it increases - ($F = 7.18$, $df = 3,6$, $p = 0.0205$, see Fig 11.3). Consequently, walking speed is the more useful measure as it summarizes the other two. Table 11.1 displays the significance levels of planned comparisons between the mean walking speeds under the different route conditions.

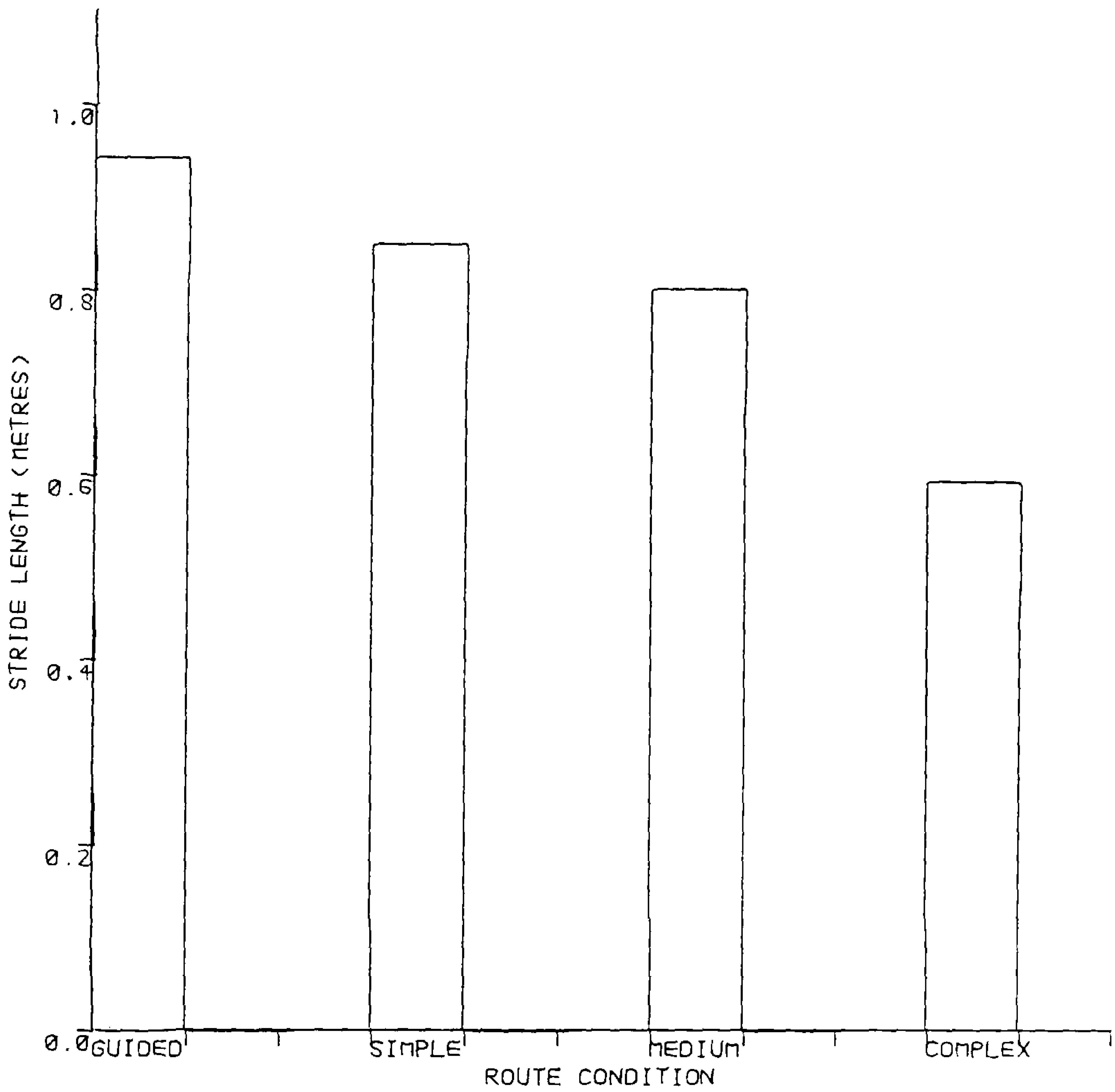

FIG 11.1: STRIDE LENGTH BY ROUTE CONDITION

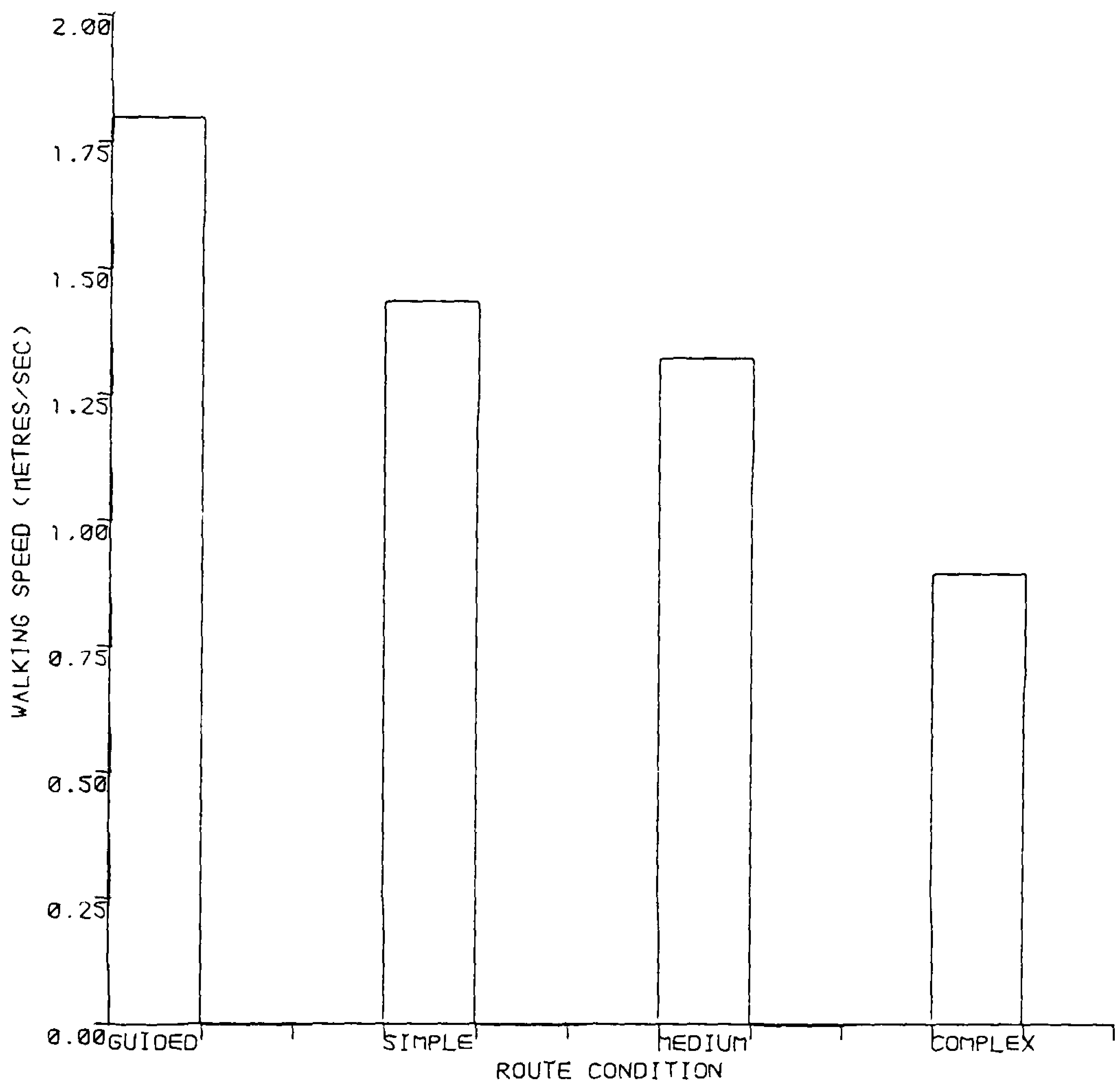

FIG 11.2: WALKING SPEED BY
ROUTE CONDITION

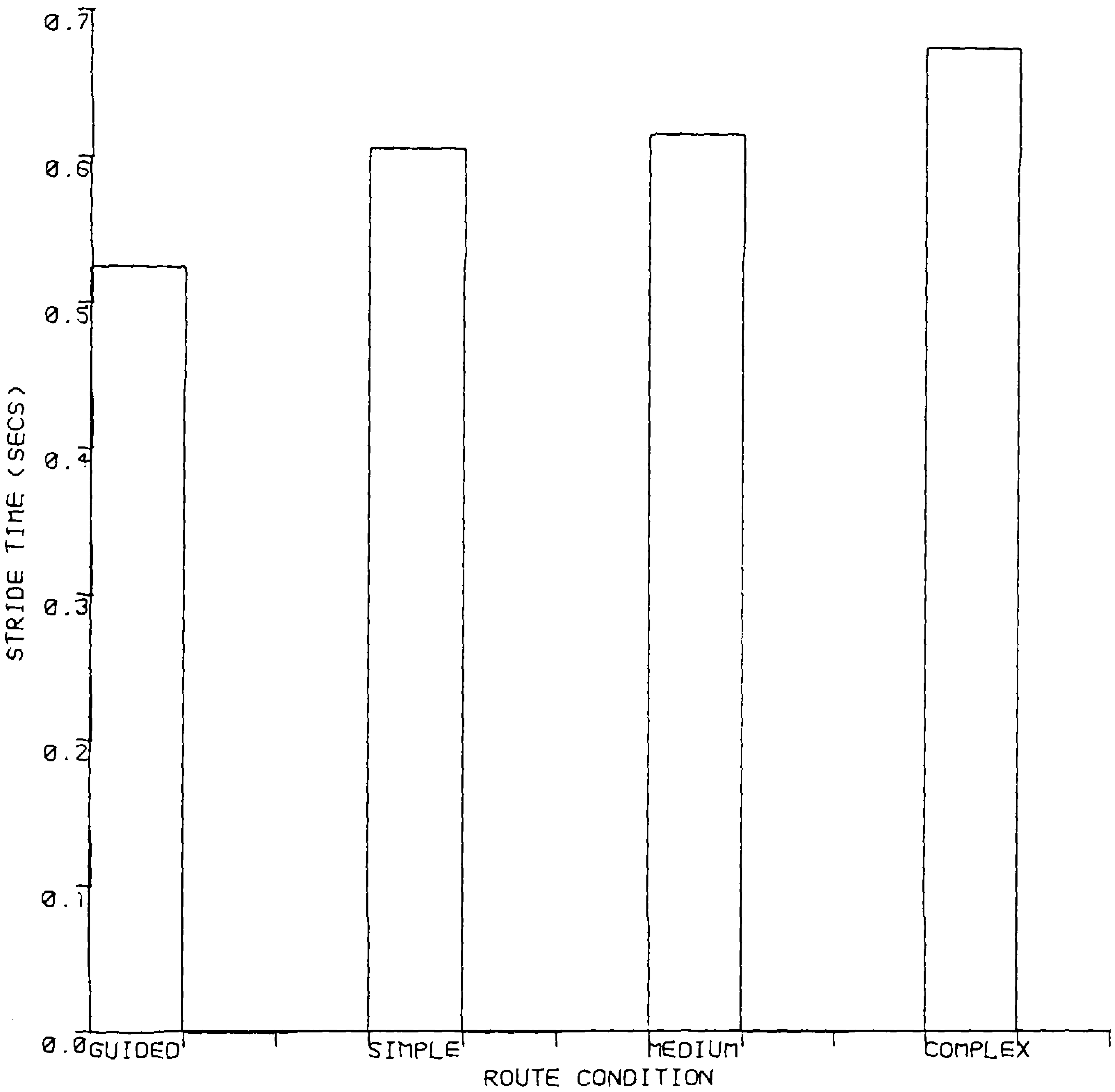

FIG 11.3: STRIDE TIME BY ROUTE CONDITION

Condition	Sighted guide	Simple	Medium	Complex
Sighted guide	-	-	-	-
Simple	0.022	-	-	-
Medium	0.006	>0.25	-	-
Complex	<0.001	0.003	0.011	-

Table 11.1: Probabilities yielded by planned comparisons of the mean walking speeds for routes of different complexity.

11.7.2 Reported Mood

Analyses of variance were carried out on the Arousal and Stress scores of subjects; these included the pre-test levels. Scores on both the Arousal and Stress dimensions showed no significant effect between conditions (Arousal: F = 1.304, df = 4,8, p = 0.346, see Table 11.2; Stress: F = 0.476, df = 4,8, p = 0.753, see Table 11.3). The range on both dimensions can be compared with those of a sighted group who took part in a study on diurnal variation in mood (Watts et al, 1983). None of the reported arousal levels were outside the normal range as given by the sighted group. The reported stress levels only exceeded those of the sighted group on two occasions: Subject One after independent completion of the simple route, and Subject Three after completion of the complex route.

Condition	Route	Mean	SD
Pre test	-	6	1.00
Guided	Simple	7	1.73
Independent	Simple	7.6	1.53
Independent	Medium	8.6	3.51
Independent	Complex	8.3	4.04

Table 11.2: The reported arousal experienced by Subjects, as assessed by the SACL. (the higher the value the greater the arousal)

Condition	Route	Mean	SD
Pre test	-	2	2.00
Guided	Simple	1.6	1.15
Independent	Simple	3.3	4.04
Independent	Medium	1.6	1.15
Independent	Complex	3.6	2.52

Table 11.3: The reported stress experienced by Subjects, as assessed by the SACL. (The higher the value the greater the stress)

11.8 Discussion

The validation study has demonstrated that both walking speed and stride length are detrimentally affected by route complexity, even during sections of the route when the pedestrian does not come in contact with obstacles. However, there is no proof that stress was the cause of this result. Both the present study, employing the SACL, and the pilot study, employing the proof-reading task, suggest that stress may be an inappropriate term, in this context.

It is obviously prudent to walk more slowly when there is a greater likelihood of contacting obstacles or when one is unsure of the path ahead. Although obvious, this does not detract from the usefulness of walking speed as an evaluation tool, for it is a measure of a pedestrian's confidence.

There are two ways in which blind pedestrians might be given the greater confidence to increase their walking pace. Firstly, they could be given extended preview of the path which lies ahead of them. Secondly, they could be provided with an aid which takes from them the responsibility for object avoidance. The next chapter describes an experiment which ascertained the optimum level of preview which one such aid, the Sonic Pathfinder, should provide in order to increase pedestrians' walking speed. And the following chapter deals with an aid - the guide dog - which takes responsibility for object avoidance.

Chapter XII

The effect of preview upon walking speed

12.1 Introduction

Only two studies have attempted to compare the effect of different levels of preview upon mobility and both used artificial indoor environments (Jansson and Schenkman, 1977; Barth, 1979). Barth used sighted subjects whose preview he limited with the use of an adjustable opaque visor. Subjects' horizons of view were restricted by the visor and they were physically prevented from making compensatory head movements. Thus, while preview was restricted, the information which was available was given visually.

He compared previews of half a step, one step, 1.5 metres and 3 metres (the distance of a 'step' differed for each subject as it was defined as their own stride length when sighted). To derive dependent measures he used both Armstrong's version of the Evaluation Package and Shingledecker's secondary task. He found that the greatest amount of preview (3 metres) allowed subjects to maintain all aspects of 'effective' mobility except that they made mistakes at turning points. With only 1.5 metres preview both their efficiency and secondary task performance were impaired. When preview was reduced to one step's length safety errors occurred.

This experiment, while theoretically interesting, is far removed from what is involved for the blind pedestrian whose preview is received through the intermediary of the display of a mobility aid.

Although Jansson and Schenken (op cit) used a mobility aid to provide preview, the aid was the

Swedish Laser Cane (see Chapter I) which has not gained wide acceptance. They varied the range of the aid between two and three metres, and found that subjects detected significantly more objects and had a longer stopping distance with the longer range. However, the longer the range the greater the number of false detections which were made. This is because the aid is being used in the same way as a long cane. Therefore, as it reaches the end of its arc on each swing the transducers are pointing out to the sides and thus producing an aid with an unnecessarily wide beam. Jansson and Schenken recommended that if the range of the Swedish Laser Cane were to be extended to three metres then the scanning technique to be used with it would have to be modified.

There is a need for a systematic comparison of levels of non-visual preview using a less complicated aid than the Laser Cane. A development of the Pathfinder which has been made since its evaluation, means that it is now an ideal tool with which to provide the preview for this study. And the wheel provides a simple means of measuring walking speed as the dependent variable.

Heyes (1984b) re-designed the Sonic Pathfinder to be controlled by an electronically programmable read-only memory (EPROM) microchip, and to include a hex switch. These alterations mean that the aid can be pre-programmed with up to sixteen alternative versions. For the purposes of this experiment these versions were different ranges. Thus, each range can be selected, in the field, simply by altering the hex switch to the appropriate position.

12.2 Design

Each subject wore both the wheel and the footswitches throughout the experiment. In addition, they wore the Pathfinder and carried a long cane. The route was a straight path with an even tarmac surface which was bounded on both sides by grass. There was one obstacle - a human - standing at one of two possible distances - 18 or 27 metres - in the centre of the path on each pass. The Pathfinder was set to have only a central beam. It utilised the musical scale, but on the two shortest ranges the scale was restricted, such that while the zones were the same size, the outer zones were not displayed. In, all four switch positions were used, giving five levels of preview: approximately 1 metre (with the aid switched off and thus relying on the cane), 1.9 metres, 2.7 metres, 3 metres and 3.5 metres.

12.3 Procedure

Once a particular range had been selected for the aid, the subject was given the opportunity to become familiar with the level of preview the aid now afforded. The experimenter, as the object to be detected by the aid, retreated until the subject reported that the aid no longer produced a signal. The subject was then asked to walk towards the experimenter until the nearest zone had been reached, then walk backwards until the aid no longer responded. This was repeated until the subject indicated that he appreciated the degree of preview which the aid now afforded. The subject walked the route six times with the aid set at that range - three passes to each distance - in a random order, before the entire procedure was repeated for the next range.

A pilot study had shown that there was a learning effect involved in the task and that this reached an asymptote by five passes of the route. To deal with this, a familiarisation phase was included, which involved the subject completing the entire procedure with the aid set at an intermediate range (2.4 metres). After familiarisation the experiment was conducted, with subjects being assigned alternately to the conditions in which they started: either with the shortest range or with the longest range. Once started they worked through the ranges in ascending or descending order depending on their starting condition.

12.4 Instructions

Subjects were told that they were to walk as fast as they felt safe, but that they were to attempt to avoid contacting the 'obstacle' either with their body or with the long cane. In avoiding the object they were asked to proceed as smoothly as they could (which would probably necessitate going onto the grass), and then to regain the path once they had passed the object. They would then continue walking until they were asked to stop, which, although not part of the instructions, was approximately ten paces after they had regained the path.

12.5 Subjects

Six subjects took part in the experiment: two were sighted and blindfolded, and the remainder were registered as blind. Only one of the subjects - a blind person - was female. All the blind people were late blinded. Their ages ranged between 25 and 60 years. One of the blind people had perception of light and one had sufficient sight to read a computer's visual display unit; none of them had guiding sight.

12.6 Results

There was a significant effect of degree of preview upon subjects' overall speed ($F=7.674$, $df=4,20$, $p<0.001$; see Fig 12.1). Planned comparisons were carried out on the mean velocity for each degree of preview to find the source of the significant differences (see Table 12.1). Subjects walked significantly faster when they had 2.7,3 or

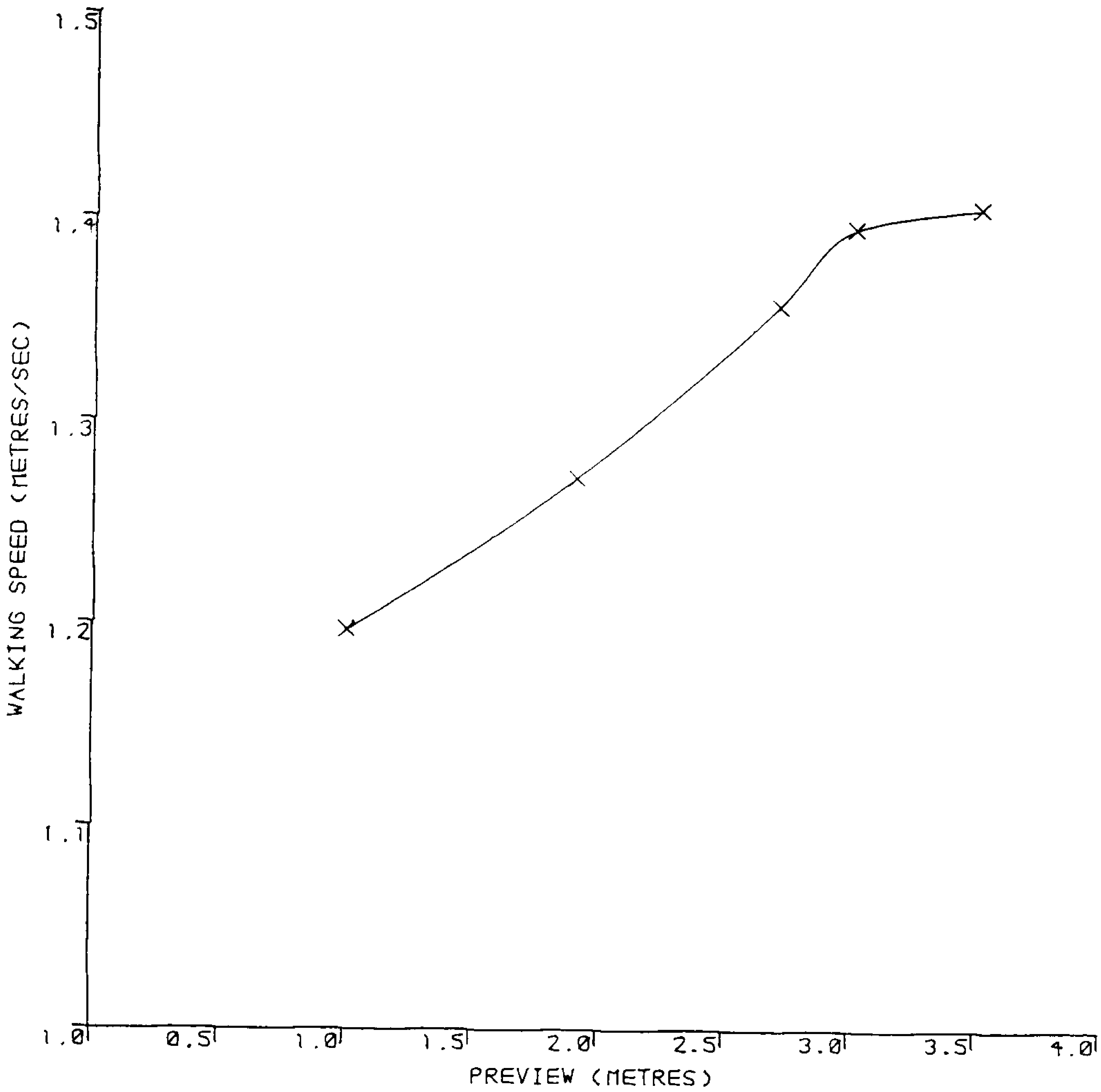

FIG 12.1: WALKING SPEED BY PREVIEW

3.5 metres preview than when they used the cane.

		preview (in metres)				
		1	1.9	2.7	3	3.5
	1	-				
	1.9	0.114	-			
preview	2.7	0.002	0.075	-		
(in metres)	3	<0.001	0.014	>0.25	-	
	3.5	<0.001	0.008	>0.25	>0.25	-

Table 12.1: Probabilities yielded by planned comparisons of mean velocity for preview levels.

12.7 Conclusions

When the Sonic Pathfinder presents users with 3.5 metres preview of obstacles lying in their path they adopt a walking speed, on a simple route, which is eighteen percent faster than the speed they adopt when preview is supplied by the long cane. If the range of the Pathfinder were increased much above 3.5 metres, then, for the person of average or below average height, the aid would receive more scattered ultra-sonics and thus begin to give false detections of non-existent obstacles. Fortunately, as the Figure 12.1 shows, walking speed appears to reach an asymptote at this range. As a result of these findings the Pathfinder's range has now been increased to 3.5 metres.

The next chapter describes an experiment in which the walking speed of guide dog users was recorded, and compared with the speed adopted by long cane users.

Chapter XIII

The effect of the Guide Dog upon walking speed

13.1 Introduction

The guide dog was introduced into this country in 1931. In 1965 Gray and Todd (1967) noted that just over three percent of those in their sample below the age of 65 years were owners of guide dogs. The proportion in the Nottingham Survey (Clark-Carter et al, 1981) of those of the same age range and registered as blind was approximately eleven percent.

Although the guide dog is a popular mobility aid among the blind, there has been little research into its effects upon mobility. Delafield and Armstrong (1977) noted that efficiency - as measured by Armstrong's evaluation procedure - was better for guide dog users than for the same pedestrians when they used a long cane. However, this experiment has a major fault. Prior to receiving guide dog training, each subject was a long cane user, and at this stage their mobility was assessed on the standard test route. Subsequently, they all underwent training with the guide dog and were retested, again on the standard test route, using their dogs. Thus, there was no control for route familiarity. Delafield and Armstrong (1977, op cit) realised that this was a problem but found that, once trained with a guide dog, subjects were unwilling to return to using the long cane.

The following experiment, which controlled for route familiarity, was carried out to compare the walking speed of guide dog, sighted guide and long cane performance.

13.2 Subjects

One male and two females took part in the experiment. All had been users of the long cane prior to owning a guide dog. They were willing to act as their own controls and perform the sighted guide, the long cane and the guide dog conditions.

13.3 Route

A reduced version of the standard test route was chosen for this experiment, with one minor modification. Before a guide dog makes a left turn it has to pass behind the person it is leading. Had any left hand turns been included on the route, the dog would have become entangled with the apparatus used to record gait. For this reason the part of the route selected was walked in the opposite direction to the one usually adopted for the test route, thereby excluding left turns.

13.4 Procedure

Each subject walked the route three times. Firstly, their preferred walking speed was established while they were accompanied by a sighted guide. Secondly, they were guided by the dog. Thirdly, they walked the route independently, using the long cane. This order was maintained for all subjects, so that their independent pass of the route was the one which benefited most from experience with the route.

Throughout the experiment gait was recorded using the wheel and footswitches.

13.5 Results

There was a significant difference in walking speed between the three passes of the route ($F = 18.05$, $df = 2,4$, $p = 0.01$; see Fig. 13.1) Planned comparisons were made of the means for the three conditions (see Table 13.1). Firstly, subjects walked significantly more slowly when they used the long cane than their preferred walking speed (PWS). Secondly, they walked significantly more slowly using the long cane than they did with the dog. Thirdly, the speed they adopted with the dog did not differ significantly from their PWS.

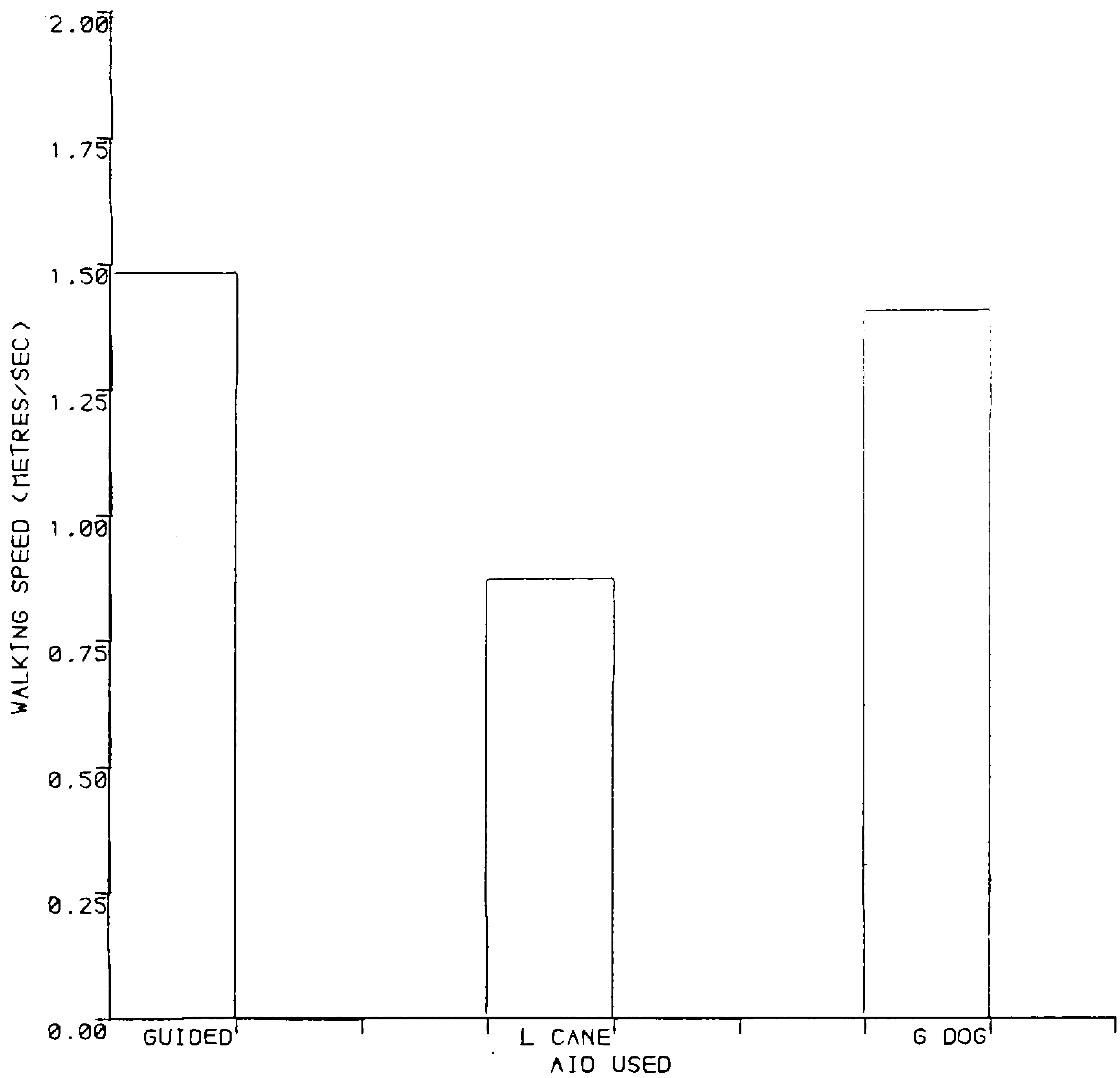

FIG 13.1: WALKING SPEED BY AID USED:
GUIDE DOG OWNERS

	Aid used		
	Sighted guide	Long cane	Guide dog
Sighted guide	-	-	-
Long cane	0.008	-	-
Guide dog	>0.25	0.005	-

Table 13.1: Probability levels for comparisons of mean walking speed of guide dog trained pedestrians walking with different aids

13.6 Discussion

The superior speed achieved with the guide dog and the sighted guide could be explained by the fact that the long cane skills of these subjects had become poor through lack of use. However, this assumption can be tested by comparing the walking speeds of the present subjects with those of the subjects who took part in the experiment on route difficulty.

The problem with such a comparison is that there is large variation in walking speeds between subjects under the same conditions. Therefore, unless subjects act as their own controls, large samples will be necessary to reduce the sample variance. In fact, those trained with a guide dog, when using their dogs, did not walk significantly faster than the long cane users ($t=0.672$, $p = 0.54$, two-tailed test; see Fig. 13.2).

However, it is possible to allow for inter-subject variability if one takes account of each individual's preferred walking speed (PWS). The speed of any pass of any route for any subject can be expressed as a Percentage of Preferred Walking Speed (PPWS), for that subject. When PPWS is employed in the comparison between long cane and guide dog users, the guide dog users are shown to walk significantly closer to their PPWS than do the long cane users to their PPWS ($t = 4.352$, $p = 0.012$, two-tailed test).

The next chapter explores PPWS more fully and proposes that it is a useful addition to the existing evaluation procedure.

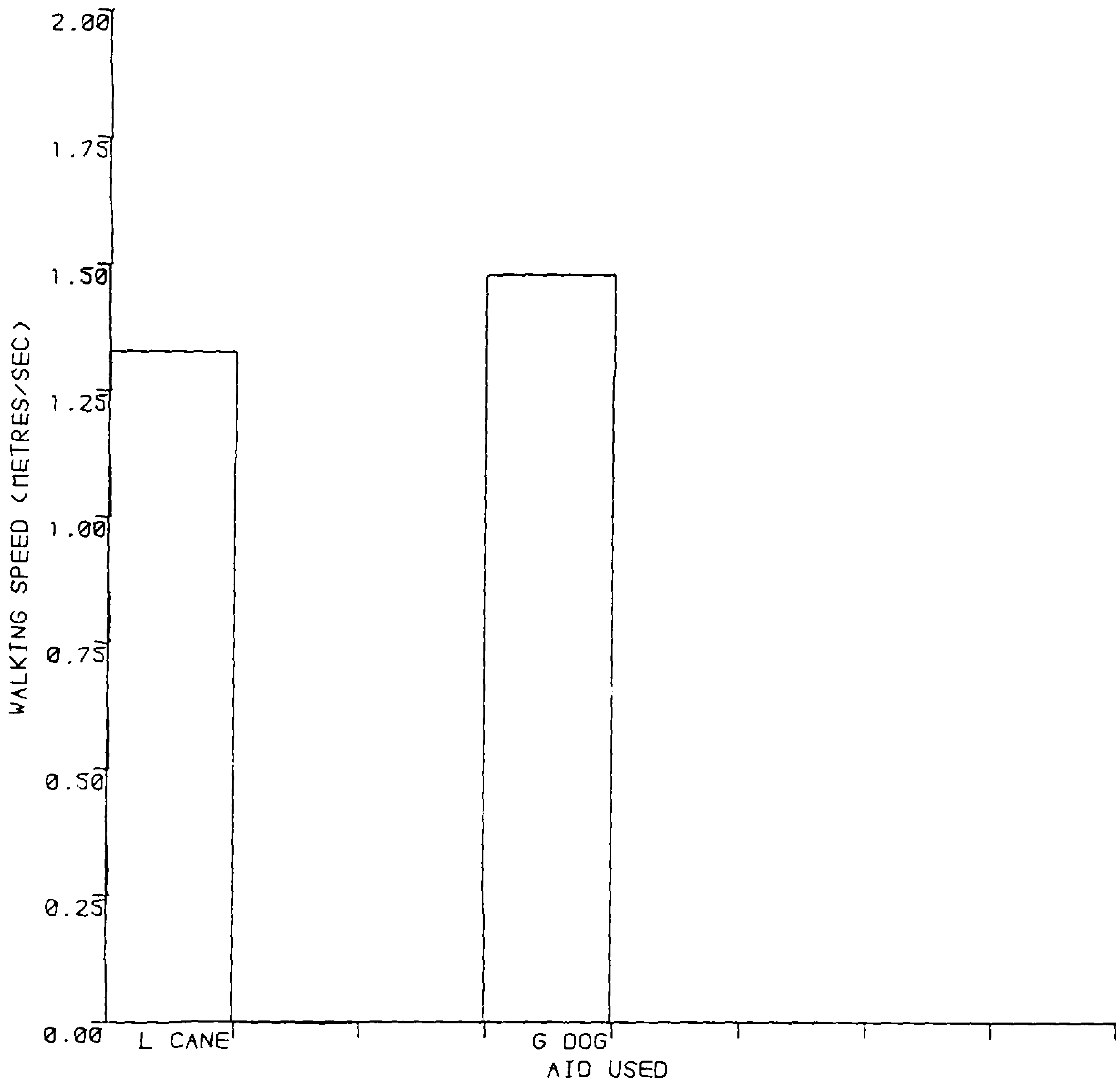

FIG 13.2: WALKING SPEED BY AID USED
LONG CANE VS GUIDE DOG USERS

Chapter XIV

Percentage of Preferred Walking Speed

14.1 Walking Speed

Cotes and Meade (1960) showed that, among sighted people, energy expenditure increases with increased walking speed. However, if one takes into account the increased distance travelled at higher speeds and replots their data it can be seen that there is an optimal walking speed at which distance travelled per unit of energy expended is at a maximum (see Fig 14.1). Waters et al (1978) report their own and others' work which shows that, on average, people prefer to walk at a speed which

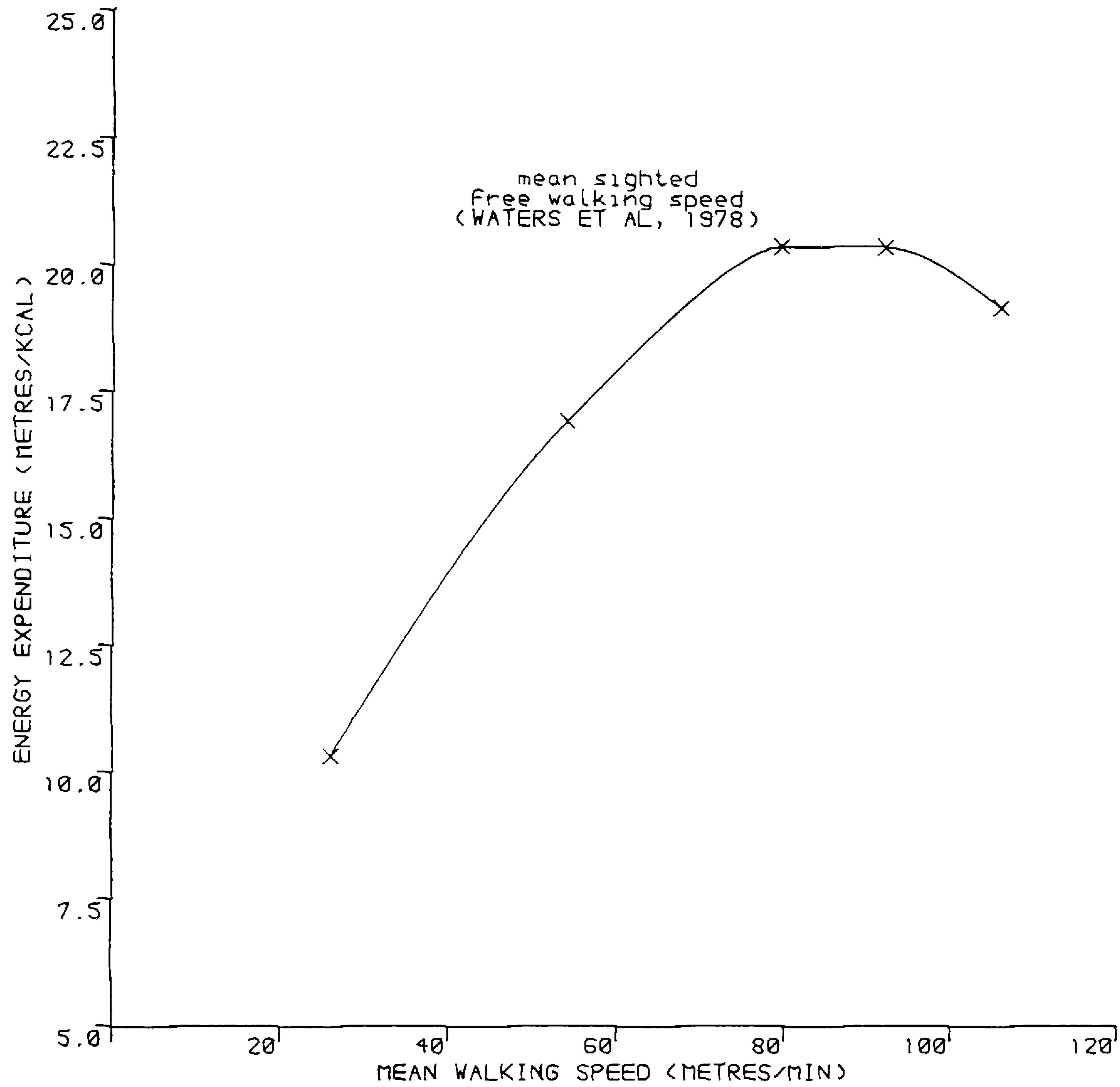

FIG 14.1: ENERGY EXPENDITURE BY WALKING SPEED - SIGHTED PEDESTRIANS (ADAPTED FROM COTES & MEAD, 1960)

is very close to that optimum.

Both the walking speed which people adopt and the relationship between walking speed and energy expenditure vary according to such factors as age, leg length and body weight. However, Ralston (1958) found that individuals naturally walk at the speed which is the most efficient for them - their preferred speed. Figure 14.2 shows a graph of physical effort, expressed as a percentage of this maximum efficiency, against walking speed, expressed as a Percentage of Preferred Walking Speed (PPWS). It is drawn according to the best fit polynomial derived by the graph plotting package 'SIMPLEPLOT':

$$Y = -5.1612 + 2.0064 \times X - 0.0094 \times X^2.$$

The research reported in this thesis has shown that a number of additional factors will affect the walking speed which a visually impaired person adopts. Among these are the complexity of the route and the type of mobility aid which is being used.

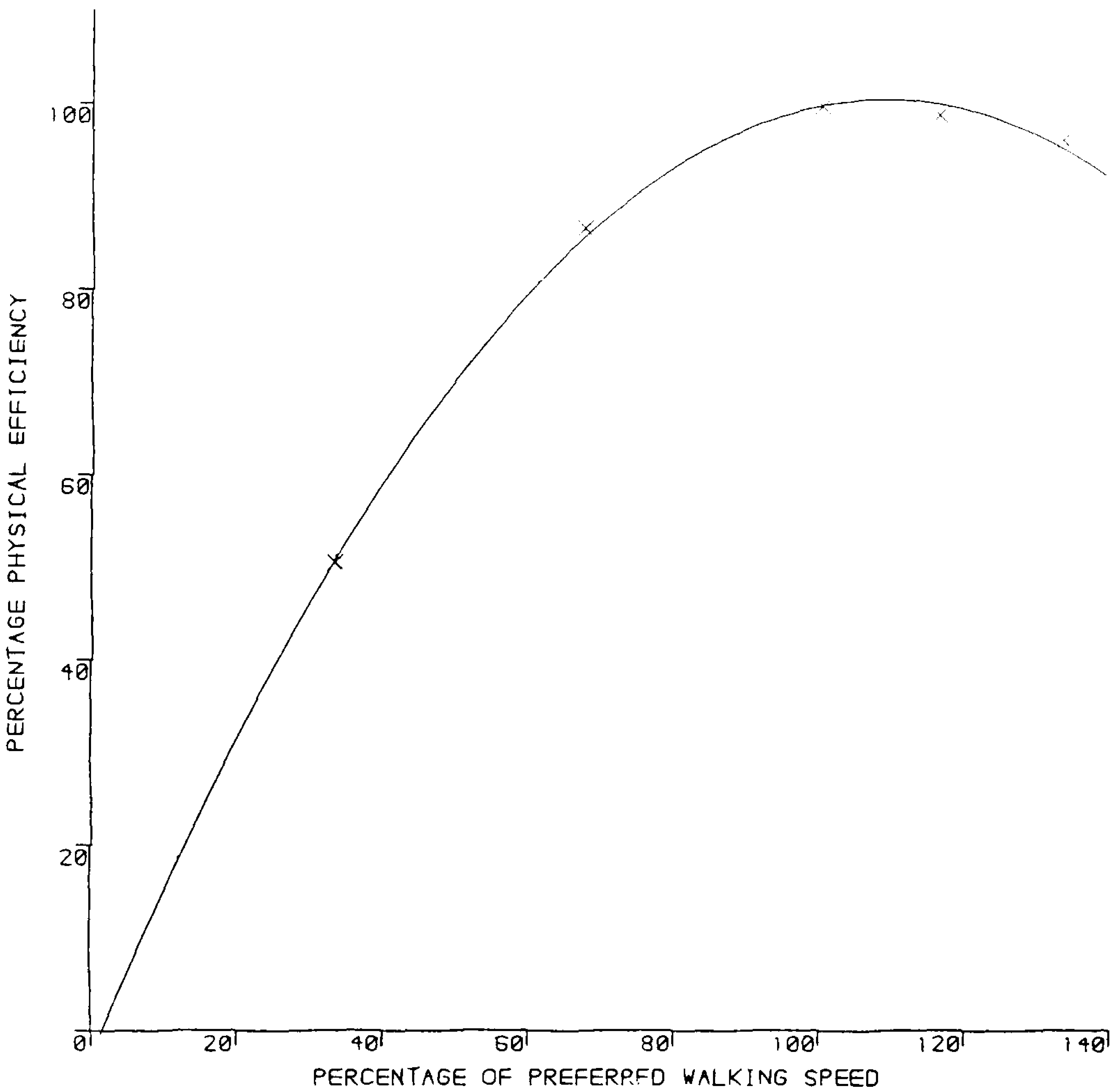

FIG 14.2: EFFICIENCY BY WALKING SPEED
SIGHTED PEDESTRIANS (PERCENTAGES)
(DERIVED FROM FIG 14.1)

14.2 The Preferred Walking Speed of the blind

It is reasonable to assume that if the blind had their sight they would walk at their Preferred Walking Speed (PWS). This assertion is supported by the fact that the six blind people whose PWS was measured walked at a mean speed of 96.5 metres/min. Reference to Fig. 14.1 shows that such a pace involves a minimum of energy expenditure for this task. The independent walking speeds reported in this thesis can be represented in terms of Percentage of PWS (PPWS), and this will show the relative physical efficiency achieved with the various aids which were used.

14.3 Route Complexity

The effect of route complexity upon the walking speed of long cane users is shown in Figure 14.3 - the speeds being expressed as PPWS and superimposed upon the curve derived from Cotes and Mead (op cit).

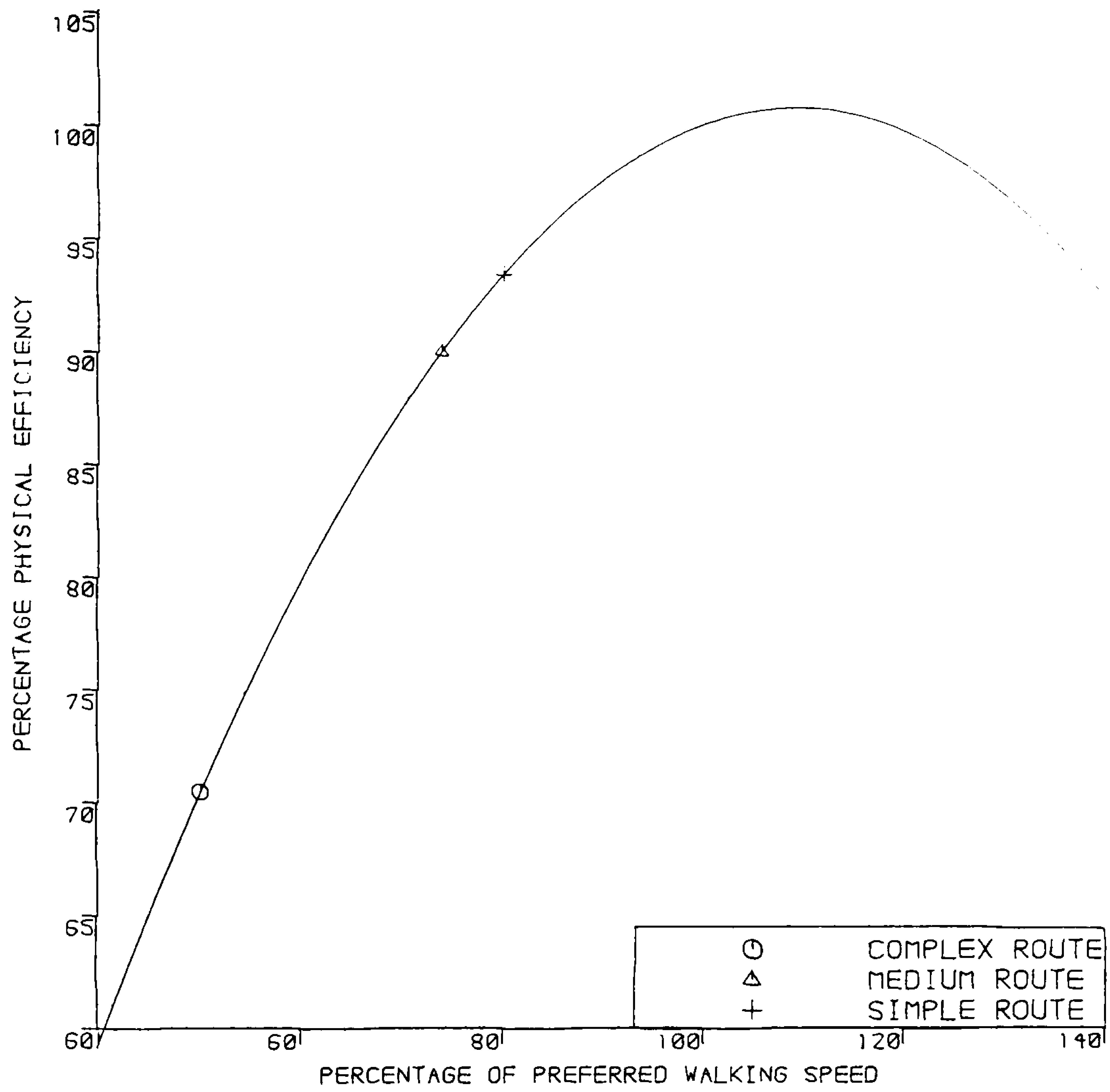

FIG 14.3: PHYSICAL EFFICIENCY BY WALKING SPEED: ROUTE COMPLEXITY (SUPERIMPOSED UPON EFFICIENCY CURVE OF FIG 14.2)

14.4 The adopted walking speed of guide dog users

Figure 14.4 shows the data comparing long cane and guide dog users. Again, the data are given in terms of PPWS and are superimposed on the curve of efficiency.

This measure shows that the guide dog enables blind pedestrians to walk at a more efficient pace than does the long cane.

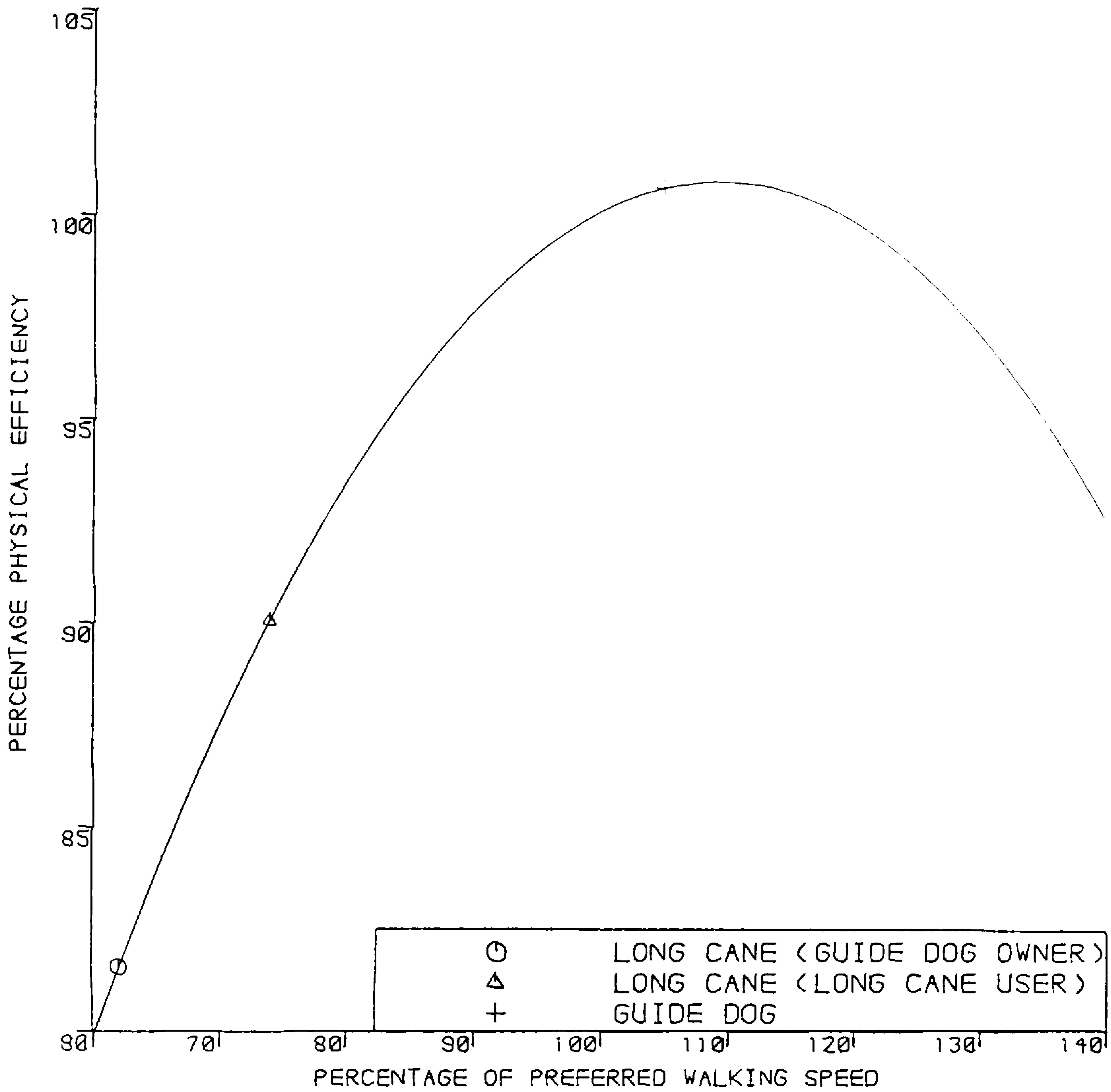

FIG 14.4: PHYSICAL EFFICIENCY BY WALKING SPEED: GUIDE DOG VS LONG CANE (SUPERIMPOSED UPON EFFICIENCY CURVE OF FIG 14.2)

14.5 Preview

Although Preferred Walking Speed was not measured in the experiment on preview, it is possible to normalize the data with respect to the known PPWS for the long cane on a comparable route. The experiment on route complexity showed that PPWS when the long cane is used over a simple route is approximately eighty percent. The results of providing additional preview are plotted on the efficiency curve shown in Figure 14.5.

It can be seen that, on a simple route, the Sonic Pathfinder can increase the efficiency of pedestrians, compared with the long cane, from ninety three percent to ninety nine percent.

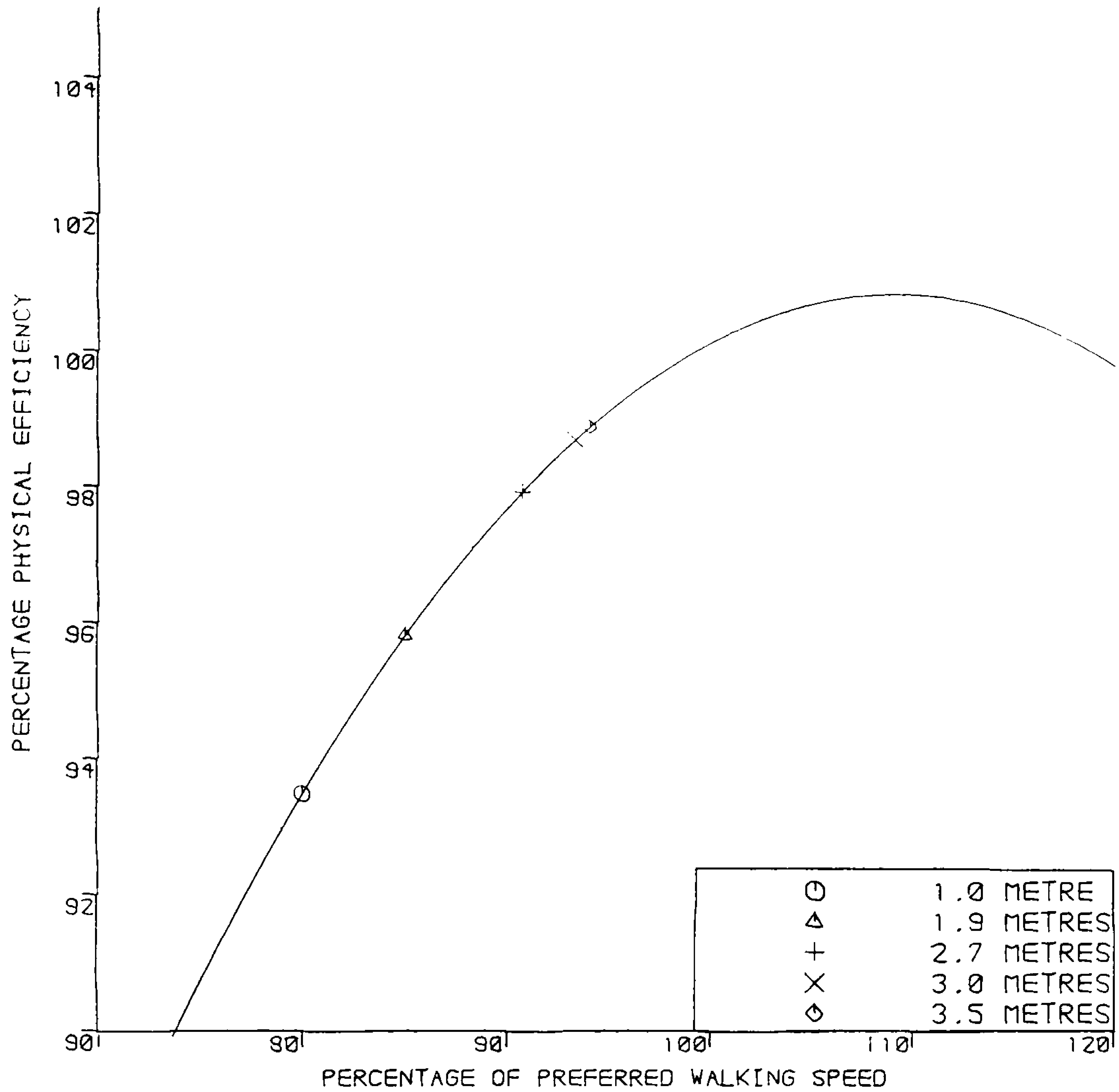

FIG 14.5: PHYSICAL EFFICIENCY BY WALKING SPEED: PREVIEW
(SUPERIMPOSED UPON EFFICIENCY CURVE OF FIG 14.2)

14.6 Discussion

There are a number of shortcomings in Armstrong's evaluation procedure. Firstly, because the people used in such evaluations have to be capable of walking the test route using only a cane, they already have to have a high level of mobility. Consequently, their performance is close to a ceiling level on many of the measures, and thus even a good mobility aid may show little improvement. Secondly, although the procedure is not aid specific - as far as the secondary aid is concerned - it is limited to the assessment of pedestrians who use a cane as a primary aid. Thirdly, each person has to act as their own control, and thus, if two aids are to be compared, each subject would have to learn to use both aids; as has been seen in the comparison between the guide dog and the long cane this is not always practical. Fourthly, although Armstrong's technique deals with safety and efficiency, it does not include a measure of the stress which blind people claim to experience.

The use of PPWS has three advantages over existing measures. Firstly, any ceiling in performance is the genuine ceiling of sighted mobility. Secondly, it is not reliant on a cane to provide scorable events, and can thus assess aids, such as the guide dog, which are not used in conjunction with a cane, or groups, such as the partially sighted, who do not use a mobility aid. Thirdly, different aids can be compared without the same subjects having to be trained to use each aid, as a score can be derived for each aid rather than for an individual subject.

Preferred Walking Speed sets a goal towards which mobility aids should aim and against which they can be evaluated. It need not be the only measure; where appropriate Armstrong's evaluation procedure should also be used. However, PWS emancipates evaluation of mobility aids from adherence to Armstrong's procedure when this is less appropriate.

Walking speed can be seen as a measure of physical efficiency. It alters as a function of route familiarity, the perceived difficulty of the route, the degree of preview which the pedestrian has of the route and the amount of trust which he can put in any aid which he is using. One term which accounts for these variations is 'confidence'; the more confident a pedestrian is the nearer he will walk to his preferred speed.

Chapter XV

General Conclusions

15.1 Introduction

A survey of the visually impaired in 1965 showed that a large proportion did not make independent journeys outside their homes (Gray and Todd, 1967). Since then the long cane has been introduced to this country, the profession of

Mobility Officer has been established and the variety of electronic mobility aids has increased. The Nottingham Survey indicates that despite these changes there has been little improvement in the mobility of the visually impaired (Clark-Carter et al, 1981). In fact, there has been no increase in the proportion who use a cane, and very few have even used, let alone owned, an electronic aid. The one change in aid usage has been an increase in the ownership of guide dogs.

15.2 Mobility Aids

15.2.1 Availability and shortcomings

The lack of improvement in the mobility of the visually impaired has two main causes. Firstly, the availability of the long cane and electronic aids is restricted. To receive a long cane one needs to be trained in its use but there are insufficient Mobility Officers to meet the demand for training. In England in 1982 (the last date for which the figures can be compiled) the ratio of Mobility Officers to people registered as blind was approximately 1:1000 (DHSS, 1982; NMC, 1982). Not all those qualified as Mobility Officers were necessarily training clients as some will have been promoted to administrative jobs. There were a further 500 people registered as partially sighted to each Mobility Officer, many of whom will also have required training. In addition, the allocation of Mobility Officers around the country is uneven, with some authorities employing none at all.

Electronic mobility aids are very expensive (the Sonic Guide costs over £1500) and visually handicapped people are often not in employment. If employed they receive a small additional tax allowance, but if unemployed they receive no financial allowance for their impairment. In addition, agencies which work on behalf of the visually impaired do not sell electronic mobility aids at subsidised prices; the failure of the Sonic Torch has made them reluctant to do this.

A second cause of the lack of improvement in mobility is that no existing mobility aid is good enough to be a surrogate for vision, and therefore each has shortcomings. Canes provide little preview and thus little warning of potential danger.

Accordingly, cane users have to be particularly alert in order that they can react quickly to any indication from their aid that they are approaching a hazard. Electronic aids, while giving more preview than the cane, have to be used in conjunction with a cane and require the user to attend to yet another set of signals which need interpretation. The guide dog, although it does the mental work for its handler, can be inconvenient and provides little information about the environment.

15.2.2 Long cane training

It might be felt that by giving people a long cane without training them one would solve the problem of access to that aid, but the research reported in this thesis shows that untrained cane users develop unsafe techniques. However, the problem could be solved if mobility officers visited clients when they were first registered as visually impaired. At this stage clients could be given one short lesson with the cane, thus enabling them to be safely mobile until their turn came to receive full long cane training.

15.2.3 Electronic Aids

The problem with electronic aids is more complicated. It is unlikely that, in their present form, even if they were provided free they would have a dramatic impact on the mobility of the visually impaired. The simple ones, while needing little or no training in their use, have the effect of extending the preview of the cane user but add little else. The more sophisticated ones do need training; the Sonic Guide course is designed to take thirty hours. Thus their use is partly dependent on the availability of Mobility Officers, who do not, in this country, receive tuition on their courses in how to teach such aids. In addition, it appears that only a minority of visually impaired people would be able to get the full benefit of such aids once they had been trained, because of the difficulties experienced in interpreting the displays.

15.3 Evaluation and aid design

The process of improving the displays of electronic aids has been hindered by two factors.

Firstly, the methods used to evaluate them have been inadequate in the past. Accordingly, it has not been possible to endorse or dismiss any aid on the basis of an objective evaluation. Secondly, as the evaluation of the Sonic Pathfinder showed, the evaluation technique is not the best way to refine an evolving aid; it is more appropriate to the assessment of a finished aid.

The Evaluation Package has now been improved and includes measures, such as the verbal commentary and the Percentage of Preferred Walking Speed (PPWS).

Where possible the parameters of an aid should be derived experimentally rather than a priori. The initial design should be treated as an hypothesis which is tested before the design is finalised. This process has been carried out on the range of the Sonic Pathfinder and has resulted in an increase in the amount of preview which that aid now provides; a series of similar experiments are to be conducted on other aspects of the Sonic Pathfinder.

15.4 Partially sighted pedestrians

A further advantage of the verbal commentary and the PPWS is that they are not dependent on the scoring of events produced by a cane user. It is known that clinical measures such as visual acuity and field are poor predictors of a client's mobility (BMRU, 1982). There has long been a need for measures of the mobility of the partially sighted, and, as the evaluation of the self-trained guide cane users showed, the original evaluation package was not equal to this task. Research is now under way which utilises these two new measures with partially sighted subjects.

15.5 Stress

One way in which blind and sighted mobility is felt to differ is the greater stress experienced by blind pedestrians. Work on heart rate has appeared to demonstrate the presence of such stress. However, the evidence derived from the use of this measure is not consistent. Wycherley and Nicklin (1970) found an effect of route familiarity, while Peake and Leonard (1971) did not. Peake and

Leonard found an effect of route difficulty, while Heyes et al (1976) did not. In addition, heart rate has not shown any correlation, on a moment-to-moment basis, with events on a route.

Errors in the performance of a secondary task have in the past appeared to show variation both between routes, according to their complexity, and within routes. However, research reported in this thesis suggests that this measure is affected mainly by contact with obstacles. Thus, as a more complex route has more obstacles so more contacts are made, with a concomitant increase in secondary task errors.

There are two other measures which researchers have argued may indicate the stress which visually impaired pedestrians are believed to experience, and they relate to gait. It had been noted that in conditions which are believed to be more stressful walking speed and stride length are both reduced. The problem with this argument is that, even if stress were not involved, it makes perfect sense to slow down when there is an increased likelihood of contacting an obstacle or of becoming lost in an unfamiliar environment.

The present research has confirmed that aspects of gait are detrimentally affected by route complexity. In addition, they are shown to be affected by limited preview and by aids whose displays involve information processing.

Walking speed is the most useful gait measure. It incorporates stride length and stride time which both alter with route complexity, degree of preview and type of aid in use. However, there has been no confirmation that this effect is the result of psychological stress.

15.6 Percentage of Preferred Walking Speed

The work on the Percentage of Preferred Walking Speed (PPWS) has shown that the speeds which most blind pedestrians adopt when they are independent are physically inefficient and therefore more fatiguing than the speeds adopted by sighted pedestrians. This may explain the aversive nature of independent mobility for the blind. It may, in turn, explain why there is such a poor level of mobility among this group and why even the most mobile tend only to make essential journeys.

15.7 The guide dog

The exceptions to the rule that visually impaired pedestrians adopt an inefficient pace occur when the pedestrian does not have to process information: namely when guided by another person or by a dog. This may partly explain the increased popularity of the guide dog, why it is perceived as a less stressful aid, and why guide dog owners do make inessential journeys, even when they are not simply giving the dog exercise.

There have been attempts in Japan to create a robot version of the guide dog. However, to date, these have been limited to following a strip which has been painted on the pavement especially for the purpose; the pedestrian is thus restricted to certain predetermined routes. Nonetheless, with improved sensing devices on robots and the invention of the 'fifth generation' computer such a development may not be so far-fetched.

One way to provide the guide dog user with more information about the route might be to use an electronic aid in conjunction with the dog; one of the subjects who took part in the evaluation of the Sonic Pathfinder uses this combination.

15.8 The future

If the mobility of visually impaired people is to improve then mobility aids will have to be devised which are tailored to their needs and those aids will have to be made more accessible.

Environmental sensors which provide a welter of information which requires processing appear only fully usable by a minority of blind pedestrians. Aitken and Bower (1982) argue that if congenitally blind children are provided with such aids at an early age then the processing will become as automatic as it is for a sense with which one is born. However, as the majority of blind people develop their impairment late in life this would not be a general solution to the problem.

The guide dog appears to have gained in popularity despite the drawbacks of its inconvenience and poor provision of information about the environment. This suggests that aids which allow their user to walk at their preferred pace and do much, if not all, of the processing of information for them are to be encouraged. The design of such aids will be helped by the experimental approach which is suggested in this thesis and practised in research reported here. The final evaluation of such aids should be improved by the expanded Evaluation Package, including the use of Percentage of Preferred Walking Speed and the spoken commentary.

There needs to be further research into the nature of stress in blind mobility. While psychological measures, such as a mood checklist, fail to show any effect, the evidence from heart rate data, though anomalous, suggests that stress is present. Walking speed may prove to be the best measure of stress in mobility, but in the absence of an external validator this must remain an hypothesis.

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List of Appendices

Appendix I

The Nottingham Survey Questionnaire

BACKGROUND HISTORY

1. How old were you when you first had trouble with your sight?

2. How old are you now?

3a. How old were you when you first went onto the partially sighted register?

3b. How old were you when you first went onto the blind register?

4. Do you think your sight had changed since you were registered? (since registered blind if has been on both registers)

5. Do you know the cause of your bad sight?

6. Did you ever to to a school specially for blind or partially sighted children?

7. Would you need help if you had to clean your own home?

8. When you get dressed, can you find your own clothes?

9. Can you make yourself a pot of tea?

10. Can you cook yourself a meal?

11. Do you know how to use a telephone?

12. Can you sign your own name?

13. Can you type a letter?

14a. (LADIES ONLY) Do you wear make-up?

14b. (If yes to 14a) Do you put it on yourself?

15. (MEN ONLY) Do you shave yourself?

16. Do you usually do your own shopping?

16a. Do you live alone?

COURSES ATTENDED AND SOCIAL LIFE

17. How much contact have you had with a home teacher or a social welfare officer?

18. (If SOME or GREAT DEAL) What did they provide?

19. Have you ever attended any social or handicraft centre for blind people?

20. Do you go now?

21. How long have you been going/did you go to the centre?

22. How often do you/did you go?

23. Would you, yourself, like more clubs or activities in

24a. (If YES to 23) What should they provide?

24b. (If NO to 23) Why not?

25. Have you been on a training course for a job since you were registered?

26. (If YES to 25) Where was this and who provided it?

27. What was your last occupation before you had trouble with your sight?

28. Have you got a job now?

29. (If YES to 28) - specify.

30. How do you usually get to work?

31. Do you usually go to work alone or with someone else?

32. How far is it to work?

33. (If NO to 28) Have you ever had a job since you have had trouble with your sight?

34. (If YES to 33) Why did you give it up? (most recent only)

35. What sort of job did you do? (most recent only)

36. We are interested to know about the difficulties people have in finding jobs. Can you tell me if you would like to have a paid job?

37. (If YES to 36) What occupation would you like to be in?

38. (If NO to 36) What are your reasons for not wanting a paid job?

39. If you are in a room in the daytime can you ever tell, by the light, where the windows are?

40. (If YES to 39) Can you ever see more than that?

41. (If NO to 39) Do you ever go out? 42. (If YES to 41) During daylight how close would you get to a lamp-post before you saw it?

43. If you are walking along a pavement can you ever see where the building/wall/hedges are?

44. If you are standing at the edge of the pavement:

(a) Could you ever see a bus go by on the other side of the road?

(b) Could you ever see a car go by on the other side of the road?

(c) Could you ever see a cyclist on the other side of the road?

45. Do you find bright sunshine troublesome when you are finding your way about?

46. Do you find it more difficult to get about when it is dark?

47. Do you watch television?

48. (If YES to 47) How far away from the screen do you sit?

HEARING

49. INTERVIEWER: Does this person appear to be having difficulties in hearing any questions?

50. Do you generally have any difficulties in hearing what people say to you?

51. Have you ever used a hearing aid?

52. (If YES to 51) Do you still use it?

53. (If NO to 52) Why not?

54. (If YES to 52) In which ear do you wear it?

55. Is it/are they body worn or ear level aids?

56. INTERVIEWER: Is this person using a hearing aid now?

57. Is your aid useful when you are talking with someone else?

58. Is your aid useful when you travel by yourself?

59. When using the aid, are you able to tell the direction sounds are coming from?

ADDITIONAL DISABILITIES

60. Have you any disability or illness apart from your visual problem?

61. (If YES to 60) What is this?

62. Do you manage to travel about outside?

63. If you were walking along a pavement and being guided by a sighted friend, could you walk at a brisk pace?

64. (If YES to 63) For how long would you be prepared to walk at a brisk pace?

MOBILITY

65. Have you ever asked for formal mobility training?

66. (If YES to 65) Did you get it?

67. (If NO to 65) Why not?

68. (If YES to 66) Who and where?

69. What mobility aids have you been taught to use?

70. What mobility aids have you used for any period of time?

71. What mobility aids do you use now?

72. TO ALL USERS OF GUIDE CANES AND SYMBOL CANES

How do you use your stick?

73. TO ALL LONG CANE USERS

Do you think your cane is the right length?

74. Do you mind standing up so I can measure the distance from your chest to the ground?

75. Can I measure your long cane too?

76. INTERVIEWER: If unable to obtain measurements, why not?

77. How much do you think your visual handicap limits the amount you get about?

78. How often would you go out in a normal week?

79. Where do you go in a normal week and how do you usually get there?

80. From the point of view of traffic, what sort of neighbourhood is this?

81. INTERVIEWER'S description.

82. Do you ever cross roads on your own?

83. (If YES to 82) Do you cross busy roads on your own?

84. Can you use an ordinary pedestrian crossing on your own?

85. Can you use an audible light-controlled crossing on your own?

86. If it were important that you go to a place half a mile from here along a route you don't already know, would you try to get there?

87. Do you find it easy to keep to the centre of the pavement whilst travelling?

88. Have you learnt any new routes over the three months?

89. How often do you use busses on your own?

90. When you are walking along the pavement during daylight and you pass a parked lorry, can you ever tell it is there?

INTERVIEWER NOTE: If the person is totally blind, see Q.39, Q.40, omit "by sight" in Q.91, Q.93, Q.95, Q.96.

91. (If YES to 90) How do you tell it is there?

92. When you are walking along a pavement which has lamp-posts can you tell they are there?

93. (If YES to 92) How do you tell they are there?

94. When you are walking along a pavement and there is a pram in your way, can you tell it is there?

95. (If YES to 94) How do you tell it is there?

96. When you are walking along the pavement and you come to a road you have to cross, how do you locate the edge of the kerb?

98. Would you be able to use maps like this?

99. (If NO to 98, or DON'T KNOW to 98) Why not?

100. Do you think raised maps would be most useful to gain more information about your home area or about new areas where you want to travel?

101. Do you know that the Nottingham Social Services have raised maps of the Victoria Shopping Centre and the City Centre?

102. Do you think you would find these maps useful?

103. If you were going on a free course to teach you to get about better which would you prefer?

104. (If RESIDENTIAL to 103) How long would you be prepared to go for?

105. Can you read print with or without a reading aid?

106. (If WITH or WITHOUT to 105) How small a print can you read? (with reading aid if used)

107. (If WITH to 105) Can you show me your reading aid?

108. (If WITHOUT to 105) Have you ever applied for a reading aid?

109. Do you find that a brighter light or reading lamp makes reading easier?

110. How often do you read printed books?

111. Why do you not read more?

112. Do you use local libraries?

113. Have you ever learnt to read braille?

114. (If YES to 113) Where?

115. How soon after you were registered did you start to learn?

116. Did you finish the braille course?

117. (If NO to 116) Why not?

118. Can you write braille?

119. (If YES to 118) How do you write?

INTERVIEWER NOTE: Omit if never worked since registered.

120. When/If you have worked since you were registered did you read braille in the course of your work?

121. Do you take any braille magazines or papers?

122. (If YES to 121) - specify.

123. Here are two sheets of braille. Which do you prefer to read from?

124. Have you ever learnt to read moon?

125. (If YES to 124) How soon after you were registered did you start to learn?

126. Do you take any moon magazines or papers?

127. (If YES to 126) - specify.

128. If you have had lessons in both moon and braille which did you have lessons in first?

TO BRAILLE AND/OR MOON READERS: (if read neither, go to Q.134)

129. How often do you read braille/moon books and/or magazines?

130. Have you ever belonged to the National Library for the Blind?

131. (If NO to 130) Why not?

132. If you could send away printed material such as recipes, letters or bank statements and have them copied into braille or moon quickly and without any charge, would you use this service?

133. If braille or moon is not available and you want to listen to something, which is most convenient for you?

TO ALL

134. Do you use the talking book service?

135. (If NO to 134) Why not?

136. How often do you listen to the radio?

137. How often do you listen to "Wednesday Club" on Radio Nottingham?

138. How often do you listen to "In Touch" on Radio 4?

139. How often do you listen to television?

140. How often do you use tapes and/or cassettes?

Appendix II

The self-trained cane users questionnaire

Name:

Address

1. How many journeys do you make in a normal week?

   a) none

   b) 0 - 5

   c) 6 - 10

   d) 11 - 20

   e) 20+

2. If some journeys made last week. What journeys did you make last week?

3. If you are in a room in the daytime can you usually tell, by the light, where the windows are?

4. If yes to 3. How many fingers am I holding up ?

5. If you are standing on the edge of the pavement can you usually see:

a) a large vehicle, such as a bus, go by on the other side of the road?

b) a car go by on the other side of the road?

c) a bicycle go by on the other side of the road?

6. which register of the visually handicapped are you on

a) blind

b) partially sighted

7. have you been trained to use:

a) a guide dog

b) a long cane

c) a guide cane

8. have you asked for mobility training but not received it?

9. If yes to 8.

A. In which aid/technique:

a) guide dog.

b) long cane.

c) guide cane.

B. How long ago did you ask for training ?

C. Why did you not receive training?

10. Do you use at present:

a) a guide dog

b) a long cane

c) a guide cane

10a. If you have not received mobility training or asked for it, why not?

11. Have you any disability or illness in addition to your visual problem ?

12. If yes to 11 specify the disability/handicap.

a) deafness

b) arthritis

c) diabetes

d) heart complaint

e) stroke

f) other, specify

13. If no change in additional disability and no journeys made in a normal week, why no journeys?

14. Would you be willing to help us with our research?

Appendix III

The Sample Commentary

(played to subjects prior to walking their walking the test route from the evaluation Package)

I've just started walking along the route now
pavement is quite smooth here
walking along quite nicely now
slight breeze to the left
one or two snags now in the pavement,
inner shoreline here
I think I'm passing a tree
maybe not, maybe a lamppost, not sure
carrying along looking for the first downkerb
nothing much happening
hear the sound of a car in the distance
could be the main road
very bad hedge here,
snagging my shoulders on it
yes, another tree, I think
and yes, here is the downkerb
I'm just re-tracing and squaring off,

ready to do a crossing

listening for traffic

sounds fairly good here

right, crossing now

I've got the upkerb

Inner shoreline, just turning right

carry along

the pavement seems fairly wide here

yes, nothing really much to report

ah, there's something,

sounds like a bus shelter

something quite big, anyway

yes, carry along here

here's somebody on the other side of the road passing

not much to report

looking for the next downkerb

yes, I've got the downkerb

turning left

and going along here using touch and drag,

looking for a lamppost

and I've found a lamppost

squaring off at the lamppost ready to cross the road

and I'm crossing

got the upkerb

turning left here

looking for the pillar box

I seem to have missed the pillar box,

so I'm just re-tracing my steps now,

touch and dragging on the pavement

and I've found the pillar box

that's the end of the route

Appendix IV

Evolution of the gait recording technique

A technique of recording gait was required which could measure both the distance covered and the time taken to travel that distance. A simple pedometer merely counts the number of steps taken and thus could only produce averages of stride length and speed for a complete route. A method of measuring distance used by surveyors is an odometer or trundle wheel, which consists of a stick attached to a wheel. It is towed or pushed by the surveyor, and each revolution of the wheel increments a counter. It was felt that if a similar device were to be towed by a pedestrian, and the time taken for each revolution of the wheel recorded, then both speed and distance could be measured.

In order to free the pedestrian's hands a harness was devised, based on the hikers' back pack, which could be worn and to which the wheel could be attached via a rod. The pivot of the wheel was housed in a box which contained a means of recording the distance through which the wheel had travelled; this arrangement was stabilised by a pair of additional wheels. To record the distance travelled by the wheel it contained a number of equidistantly spaced holes whose centres were a constant distance from the circumference. As the wheel turned a beam of light projecting from one side of it through the holes to a sensor on the other side was broken and remade. This event was converted to a 2.5 Hz signal and recorded on an audio tape or transmitted via a radio link to the sound track of a video tape.

The data from the wheel were passed through a decoder to the memory of an Acorn BBC Model B micro computer and then passed on to a PDP 11-44; the BBC micro is used as an intermediary in order that the time of each event can be noted and this would not be possible using the PDP 11-44 as it utilizes a time-sharing operating system. A program was then applied to the data which converted them into three graphs plotted against accumulated time: one of the distance travelled, one of the velocity, and one of the time of each break in the light beam. The program also calculated means and standard deviations of the all these measures, and total distance and time.

It was found that the number of holes in the wheel which was necessary to provide sufficiently fine detail for analysis was six. Nonetheless, this provided large quantities of data, even when the pedestrian only travelled a short distance (approximately one data point for every ten centimetres travelled). Because most points on the body do not maintain a constant horizontal velocity (Murray, 1967*), when the pedestrian walked at a steady pace the graphs resembled those for a sign wave. However, less constant pace produced graphs which had no obvious pattern.

*Murray, M.P.(1967) Gait as a total pattern of movement. American Journal of Physical medicine, Vol 46, 290-333.

Fourier analysis distinguished between grossly different conditions such as the graph produced by a sighted pedestrian and by the same person when under blindfold, but it did not provide any information in addition to that gleaned from simply looking at the original graphs.

It was felt that the graphs would be more useful if they were more concise. This could be achieved if a larger unit of distance was adopted than part of a turn of the wheel. It was obviously better to take a naturally occurring event, or quantum of distance, - a stride length - rather than an arbitrary number of turns.

To record the occurrence of a stride a pressure pad was placed in each of the pedestrian's shoes. As pressure was placed on the pad a circuit was made, and this information was also converted into audible pulses (800 Hz and 500 Hz) for recording on an audio or video tape. Pilot work showed that even on a more complex route smooth progress could be identified for some of the time and could easily be distinguished from less smooth progress (see Figures A4.1, A4.2 and A4.3); both conditions were confirmed by reference to video recording of the pedestrian's progress.

elapsed time (secs)	distance (metres)	stride length (metres)	Distance Travelled
140.448	112.706	0.763	l
141.111	113.469	0.763	r
141.821	114.341	0.872	l
142.436	115.104	0.763	r
143.091	115.976	0.872	l
143.710	116.848	0.872	r
144.323	117.611	0.763	l
144.959	118.483	0.872	r
145.577	119.355	0.872	l
146.205	120.118	0.763	r
146.809	120.990	0.872	l
147.416	121.862	0.872	r
148.036	122.734	0.872	l
148.679	123.497	0.763	r
149.306	124.369	0.872	l
149.939	125.241	0.872	r
150.558	126.004	0.763	l
151.335	126.876	0.872	r
152.034	127.639	0.763	l
152.718	128.511	0.872	r
153.354	129.274	0.763	l
153.965	130.146	0.872	r
154.641	130.909	0.763	l
155.436	131.781	0.872	r
156.228	132.326	0.545	l
156.651	132.435	0.109	r
157.386	132.544	0.109	l
158.179	132.980	0.436	r
158.801	133.089	0.109	l
159.556	133.198	0.109	r
159.667	133.307	0.109	l
160.631	133.634	0.327	l
161.377	134.070	0.436	r
162.084	134.724	0.654	l
162.850	135.378	0.654	r
163.598	135.923	0.545	l
164.355	136.577	0.654	r
165.103	137.340	0.763	l
165.847	138.212	0.872	r

Fig A4.1. Stride length plotted against accumulated time and accumulated distance. (A subject walking over a route of intermediate difficulty using the long cane - passing a driveway and making a cane contact with the inner shoreline.)

elapsed time (secs)	velocity (M/sec)	Walking speed
140.448	1.120	*
141.111	1.151	*
141.821	1.228	*
142.436	1.241	*
143.091	1.331	*
143.710	1.409	*
144.323	1.245	*
144.959	1.371	*
145.577	1.411	*
146.205	1.215	*
146.809	1.444	*
147.416	1.437	*
148.036	1.406	*
148.679	1.187	*
149.306	1.391	*
149.939	1.378	*
150.558	1.233	*
151.335	1.122	*
152.034	1.092	*
152.718	1.275	*
153.354	1.200	*
153.965	1.427	*
154.641	1.129	*
155.436	1.097	*
156.228	0.688	*
156.651	0.258	*
157.386	0.148	*
158.179	0.550	*
158.801	0.175	*
159.556	0.144	*
159.667	0.982	*
160.631	0.339	*
161.377	0.584	*
162.084	0.925	*
162.850	0.854	*
163.598	0.729	*
164.355	0.864	*
165.103	1.020	*
165.847	1.172	*

Fig A4.2. Speed of stride plotted against accumulated time. (A subject walking a route of intermediate difficulty using a long cane - passing a driveway and making a cane contact with the inner shoreline.)

elapsed time (secs)	stride time (msecs)	Time taken
140.448	681	*
141.111	663	*
141.821	710	*
142.436	615	*
143.091	655	*
143.710	619	*
144.323	613	*
144.959	636	*
145.577	618	*
146.205	628	*
146.809	604	*
147.416	607	*
148.036	620	*
148.679	643	*
149.306	627	*
149.939	633	*
150.558	619	*
151.335	777	*
152.034	699	*
152.718	684	*
153.354	636	*
153.965	611	*
154.641	676	*
155.436	795	*
156.228	792	*
156.651	423	*
157.386	735	*
158.179	793	*
158.801	622	*
159.556	755	*
159.667	111	*
160.631	964	*
161.377	746	*
162.084	707	*
162.850	766	*
163.598	748	*
164.355	757	*
165.103	748	*
165.847	744	*

Fig A4.3. Stride duration plotted against accumulated time. (A subject walking a route of intermediate difficulty using a long cane - passing a driveway and making a cane contact with the inner shoreline.)

Appendix V

The computer program for analysis of gait data

(written in the Pascal language)

```
(* reads a file each line of which contains one of
three possible events and the time since the last
event.  Produces three files each containing a
graph: stride length, time of stride and speed of
stride.  Calculates means and sds for each of these
*)
program test(infile,outfile,outfile2,outfile3);
var     footclick,foottime,footsteps,clicks,temptime,
        time,event         :integer;
        distance,footlength,sofslength,sdtime,sdlength,
        sdvel              :real;
        meantime,meanlength,meanvel,sofstime,sofsvel,
        sumvel             :real;
        totaltime,walktime,velocity            :real;
        outfile3,outfile2,infile,outfile       :text;
```

```
(* write final statistics to first file *)
procedure writeout;
begin
        writeln(outfile);
        writeln(outfile,
        'Total number of steps taken: ',footsteps:10);
        writeln(outfile,
        'Total time: ',totaltime:10:3,' secs');
        writeln(outfile,
        'Walking time: ',walktime:10:3,' secs');
        writeln(outfile,
        'Distance travelled: ',distance:10:3,' Metres');
        writeln(outfile,
        'Mean duration of steps: ',meantime:10:3,' secs')
        writeln(outfile,
        'sd of step duration: ',sdtime:10:3);
        writeln(outfile,
        'Mean step length: ',meanlength:10:3,' Metres');
        writeln(outfile,
        'sd of step length: ',sdlength:10:3);
        writeln(outfile,
        'mean velocity: ',meanvel:10:3,' Metres/sec');
        writeln(outfile,
        'sd of velocity: ',sdvel:10:3);
end;
```

```
(* read line of data *)

procedure getevent;

begin

        readln(infile,event,time);

end;

(* initialize values *)

procedure setnoughts;

begin

        distance := 0;

        totaltime := 0;

        footsteps := 0;

        sumvel := 0;

        footlength := 0;

        foottime := 0;

        sofsvel := 0;

        sofstime := 0;

        sofslength := 0;

        clicks := 0;

        temptime := 0;

end;
```

```
(* augment statistics *)
procedure footstat;
begin
        if event mod 2 = 0 then
        (* no wheel clicks *)
                foottime := temptime + time
        else
                foottime := temptime;
        temptime := 0;

        if clicks > 0 then
        (* footstep taken *)
                begin
                footsteps := footsteps + 1;
                walktime := walktime + foottime/1000;
                sofstime := sofstime + sqr(foottime/1000)
                end;

        footlength := clicks * 0.109;
        (* 6 holes in 65.4 cm wheel *)
        footclick := clicks;
        velocity := footlength/(foottime/1000);
        sumvel := sumvel + velocity;
        sofsvel := sofsvel + sqr(velocity);
        distance := distance + footlength;
        clicks := 0;
```

```
        sofslength := sofslength + sqr(footlength);
        totaltime := totaltime + foottime/1000;
end;

(* increment click count and time *)
procedure wheelstat;
begin
        clicks := clicks + 1;
        temptime := temptime + time;
end;

(* output graphical representation of data.
Called by 'graph' *)
procedure makegraph(either :real; bin :integer;
        var  fileA :text);
var i,thistime  :integer;
begin
        if bin < 8 then
                begin
                write(fileA,chr(9));
                while footclick > 0 do
                        begin
                        write(fileA,' ');
                        footclick := footclick -1
                        end;
                if (event = 3) or (event = 2) then
```

```
                    (* left foot *)
                            writeln(fileA,'l')
                    else if (event = 5) or (event = 4) then
                    (* right foot *)
                            writeln(fileA,'r')
                    else if (event = 7) or (event = 6) then
                    (* both feet *)
                            writeln(fileA,'b');
                    end
            else
                    begin
                    thistime := round(either/10);
                    while thistime >= 8 do
                            begin
                            write(fileA,chr(9));
                            thistime := thistime - 8
                            end;
                    if thistime > 0 then
                            for i := 1 to thistime do
                                    write(fileA,' ');
                            writeln(fileA,'*')
                    end;
    end;
```

```
(* output numerical representation of data
to each file *)
procedure graph;
begin
        write(outfile,
        totaltime:8:3,distance:8:3,footlength:6:3);
        makegraph(footlength,event,outfile);
        write(outfile2,totaltime:8:3,foottime:6);
        makegraph(foottime/2,8,outfile2);
        write(outfile3,totaltime:8:3,velocity:8:3);
        makegraph(velocity*300,8,outfile3);
end;

(* calculate standard deviation *)
function standdev(a,b :real;n :integer) :real;
begin
        standdev := sqrt((a - sqr(b)/n)/(n - 1))
end;
```

```
(* make final statistical calculations *)
procedure compute;
begin
     meantime := walktime/footsteps;
     meanlength := distance/footsteps;
     sdtime := standdev(sofstime,walktime,footsteps);
     sdlength := standdev(sofslength,distance,footsteps);
     meanvel := sumvel/footsteps;
     sdvel := standdev(sofsvel,sumvel,footsteps);
end;

begin   (* main program *)
reset(infile);
rewrite(outfile);
rewrite(outfile2);
rewrite(outfile3);

setnoughts;

writeln(outfile,'Distance Travelled');
writeln(outfile,'elapsed  distance stride');
writeln(outfile,'  time              length');
writeln(outfile2,'Time taken');
writeln(outfile2,'elapsed  stride');
writeln(outfile2,'   time   time');
writeln(outfile3,'Walking speed');
writeln(outfile3,' elapsed  velocity');
```

```
writeln(outfile3,'    time');

getevent;        (* ignore first line of data *)
while not eof(infile) do
        begin
        getevent;
        if (event > 0) and (event < 8) then
        (* event from expected channels *)
                begin
                if event mod 2 = 1 then
                (* wheel clicked *)
                        wheelstat;
                if event > 1 then
                (* foot step taken *)
                        begin
                        footstat;
                        graph
                        end
                end;
        end;
compute;
writeout;
end.
```

Appendix VI

The Computer program for preparing the secondary task data

(the output from this program is fed into a previously existing program. The language used is PASCAL)

```
(* reads file of secondary task data and prepares it
for the program sectas.out. Removes errors
introduced by decoding process: double readings
which occur within one second of each other and
stimuli which are less than one sec. apart.
Separates single readings which are due to
coincidences of stimulus and response or two
responses *)

program dfilter(infile,outfile);
var totaltime,lastevent,event,oldtime,time  :integer;
    careful,starttimer                      :boolean;
    infile,outfile  :text;

procedure eventout(channel,clockval     :integer);
begin
```

```
writeln(outfile,channel:2,clockval:7)
end;

begin  (* main program *)
reset(infile); rewrite(outfile);
starttimer := false;
(* allows first stimulus through *)
totaltime := 1001;
(* allows first stimulus occurance through *)
writeln(outfile,'5     0');
(* convention for sectas.out program *)
while not eof(infile) do
        begin
        readln(infile,event,time);
        if starttimer then
        (* if last stimulus was writable reset timer *)
                totaltime := 0;
        totaltime := totaltime + time;
        if (event = lastevent) or
        ((event > 7) and (totaltime < 1000)) then
                careful := true
        else
                careful := false;
        if careful and (time < 1000) then
                begin
                oldtime := time;
```

```
        starttimer := false;
        end
else
        begin
        time := oldtime + time;
        case event of
                2:      eventout(4,time);
                4:      eventout(3,time);
                6:      begin
                        eventout(3,time);
                        eventout(4,0)
                        end;
                8:      eventout(2,time);
                10:     begin
                        eventout(4,time);
                        eventout(1,0)
                        end;
                12:     begin
                        eventout(3,time);
                        eventout(1,0)
                        end;
                16:     eventout(1,time);
                18:     begin
                        eventout(4,time);
                        eventout(1,0)
```

```
                                        end;
                               20:      begin
                                        eventout(3,time);
                                        eventout(1,0)
                                        end;
                  end;
                  if event > 7 then
                           starttimer := true
                  else
                           starttimer := false;
                  lastevent := event;
                  oldtime := 0
                  end
         end;
writeln(outfile,'5       55')
(* convention for sectas.out program *)
end.
```