Project ACTION

Detectable Warnings: Safety and Negotiability on Slopes for Persons Who are Physically Impaired

Easter Seals

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DETECTABLE WARNINGS:

SAFETY AND NEGOTIABILITY ON SLOPES

FOR PERSONS WHO ARE PHYSICALLY IMPAIRED

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Assistance derived from the Federal Transit Act, as amended, through a Cooperative Agreement with the U.S. Department of Transportation, Federal Transit Administration and Project ACTION of the National Easter Seal Society. Additional support provided under a cooperative agreement with the U.S. Department of Transportation, Federal Transit Administration, under contract to Volpe National Transportation Systems Center.

All research was performed on property of the Massachusetts Bay Transportation Authority (MBTA), with extensive support from and cooperation by MBTA staff.

ACKNOWLEDGMENTS

I am indebted to Elga Joffee, Chairperson, American Foundation for the Blind, for moral support as well as technical assistance at numerous critical junctures in this project.

Insightful questions, observations and suggestions by Dennis Cannon, U.S. Architectural and Transportation Barriers Board, Raymond Lopez, Federal Transit Administration, William Bregoli, Massachusetts Bay Transportation Authority, and Pat Ryan, Volpe National Transportation Systems Center, helped to assure accuracy and relevance of the content of this report.

The research reported in this publication was managed in large part by Tina Nolin, Ph.D., with the assistance of Winifred De Karksi, R.P.T.A., and Philip Di Joseph, Video Technician. They endured untold hours together in challenging, often cold and damp, situations in order to collect the data which are the substance of the research.

My greatest indebtedness, however, is to those persons with disabilities who participated in this research, putting up with inconveniences and interruptions in their own lives, to complete our prescribed tasks and to share their insights. It is only because of their commitment to accessible transit for all people that such research can take place.

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INTRODUCTION

Detectable warning surfaces comprised of truncated domes are required by the Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG), which were adopted by the Department of Transportation as Standards for Accessible Transportation Facilities (*Federal Register*, Sept. 6, 1991). Persons with physical disabilities and their advocates are concerned that use of detectable warnings, particularly on slopes, will make it more difficult for them to negotiate slopes, and will also result in unsafe conditions. Specifications for detectable warnings are as follows:

> **4.29.2 Detectable Warnings on Walking Surfaces.** Detectable warnings shall consist of raised truncated domes with a diameter of nominal 0.9 (23 mm), a height of nominal 0.2 in (5 mm) and a center-to-center spacing of nominal 2.35 in (60 mm) and shall contrast visually with adjoining surfaces, whether light-on-dark, or dark-on-light.
>
> The material used to provide contrast shall be an integral part of the walking surface. Detectable warnings used on interior surfaces shall differ from adjoining walking surfaces in resiliency or sound-on-cane contact.

Section 4.7.7 requires that curb ramps have detectable warnings:

> **4.7.7 Detectable Warnings.** A curb ramp shall have a detectable warning complying with 4.29.2. The detectable warning shall extend the full width and depth of the curb ramp.*

This project was undertaken to provide both objective and subjective measures of negotiability and safety for detectable warning surfaces; measures were obtained on nine representative warning surfaces (on slopes of 1:12), in comparison with brushed concrete (on slope of 1:12), by 40 persons having various physical impairments. The information provided by this research is intended to aid regulatory agencies in refining guidelines and giving

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* The ATBCB has voted to temporarily suspend this requirement until January 1996, pending further research. As of the date of this publication, this decision had not yet been published as a final rule.

technical assistance in implementation of the Americans with Disabilities Act, and to assist public and private agencies and individuals who are faced with the necessity of choosing particular detectable warning surfaces for particular applications.

This project was sponsored jointly by the Department of Transportation, Federal Transit Administration, Volpe National Transportation Systems Center, and by Project ACTION. All research was carried out in facilities of the Massachusetts Bay Transportation Authority (MBTA). The MBTA constructed laboratory facilities, provided videotaping, and maintained the research site in a safe and usable condition.

The MBTA has provided leadership in the area of detectable warnings since 1987, when they were the first of the older transit systems to install a detectable warning surface (complying with the specifications now in ADAAG) on both platforms of a rail rapid transit station. At their urging, and under their guidance, manufacturers in the tile, metal and concrete industries developed prototype detectable warning surfaces prior to the issuance of ADAAG. The MBTA continues to maintain leadership in this area, having installed (as of 07-02-93) detectable warnings on all platforms in 20 stations, including both rapid rail and commuter rail. They have installed full platform edgings of 8 different detectable warning materials, over both cement and asphalt substrates. In addition, test areas of 6 detectable warning surfaces have been installed in high use areas, including one surface installed at the top of a stair run. There have been no reports of trips, slips or falls which have appeared to be or been claimed to be attributable to these numerous installations. Furthermore, the installation of truncated dome detectable warnings continues to have the support of the MBTA Special

Needs Advisory Committee, including consumers and advocates representing people with various disabilities.

A Steering Committee comprised of 10 members representing transit, public works, persons who are physically disabled, persons who are visually impaired, and advocates for persons with disabilities gave guidance on research methods, choice of surfaces to be used in testing on slopes, and interpretation of results. (See Appendix A for the names and roles of these persons.) In addition, members were active in obtaining research participants with disabilities.

A. G. Haggart provided two staff members, Linda Desmarais, M.P.H, R.P.T., and Susan Craig, Ph.D., to aid in the development of the specific research paradigm. L. Desmarais helped to refine the video rating scale, which appears to be unique in its ability to obtain an objective measure of safety and negotiability for persons with varied physical disabilities and using various aids. In addition, L. Desmarais provided a professional interpretation of the video results from the perspective of the discipline of, and many years of experience in, physical therapy.

REVIEW OF THE LITERATURE

Research on safety and negotiability of detectable warning surfaces began in the mid-1980's with research conducted at BART (San Francisco) in which 24 persons who were physically disabled negotiated across and along two types of detectable warnings on platform edges (Peck & Bentzen, 1987). Ten participants used electric wheelchairs, four used manual wheelchairs, and ten used various walking aids or had gait problems. All participants also rated the surfaces on the extent to which they would be anticipated to impair ease of travel on BART.

All participants were able to perform all experimental tasks on both detectable warning surfaces regardless of whether they used electric or manual wheelchairs or walked with difficulty. More than 80% of participants judged that the tile would help, not affect, or would insignificantly affect their travel on BART. No participant anticipated that either surface would seriously impair his or her travel on BART. There were nine spontaneous responses that one or both surfaces would be helpful in travel. Eight of the nine "helpful" responses were from participants in the sub-group who walked with difficulty.

Following this research, a detectable warning surface material (Pathfinder Tile-resilient), was installed on all platforms of all stations in BART. After more than six years of continuous use in all stations, visually impaired riders are very pleased with the warnings, and no individual rider or group of riders has expressed dissatisfaction with the truncated dome material (Personal communication: Ralph Weule, Safety and Security, BART, 1994). The overall incidence of trips, slips and falls at the platform edge appears to have decreased; BART riders tend to stand farther from the platform edge than San Francisco Municipal Railway (MUNI) riders standing in the same stations, but at different tracks not having detectable warnings (McGean, 1991).

The research at BART was replicated by Metro-Dade (Miami) in 1986, using just the resilient Pathfinder Tile (Mitchell, 1986). Similar results were obtained. Installation of resilient Pathfinder Tile was subsequently completed on all Metro-Dade heavy rail and metromover platforms in 1990. As in San Francisco, there has been no individual or group of riders expressing dissatisfaction with the tiles (Personal communication, A. Hartkorn, Safety, Metro-Dade, 1994).

OVERVIEW OF THIS RESEARCH

Following publication of ADAAG, manufacturers working in a variety of materials quickly began producing a number of different detectable warning products intended to comply with the specifications. These products now include ceramic, hard composite and resilient tiles, cast pavers, pre-cast concrete and concrete stamping systems, stamped metal, rubber mats, and resilient coatings. These products, while typically falling generally within the specifications, differ somewhat from each other in dome dimensions and inter-dome spacing, as well as in material and in the presence, for some products, of additional texture elements intended to increase slip resistance.

Some manufacturers have varied the dimensions deliberately (while still maintaining a truncated dome pattern) in attempts to create surfaces which, while being highly detectable under foot, may be less likely to cause trips, slips and falls, particularly for persons having physical impairments and for women in high heels. In addition, as different industries have attempted to create detectable warnings using different materials, standard dimensions in some industries, most notably tile and paver dimensions, have made it difficult to achieve the specified geometry or to hold the geometry constant across adjoining units of the detectable warnings surfaces.

This research was undertaken to provide human factors data documenting the effects of detectable warning surfaces, of varied dimensions and fabricated of various materials, on negotiability and safety for persons having a wide variety of physical disabilities. Previous research and accumulated experience documenting minimal difficulties had been obtained only on level transit platforms. The specific charge of this research was to examine safety and negotiability of detectable warning surfaces, on slopes, for persons having physical disabilities. It is important that an accessibility feature which assists some segments of the population not do so at the expense of others. The installation of curb ramps, needed by persons who are unable to negotiate curbs, unfortunately removes the cue most reliably detectable to persons with visual impairments that they have arrived at a street. Thus ADAAG provided for curb ramps to have detectable warnings.

A pilot test was conducted in order to choose, from 15 surfaces, most of which had been demonstrated to be highly detectable under foot to persons who are blind (Bentzen, et al. 1994), nine surfaces for testing on slopes. Eleven persons having various physical disabilities negotiated the 15 detectable warning surfaces as installed on a level platform and then rated each surface for safety and negotiability. The project Steering Committee then chose nine surfaces which were highly detectable, and rated relatively safe and negotiable in pilot testing, for extensive testing on slopes.

Those nine detectable warning surfaces were then tested by 40 persons varying considerably in their physical disabilities, travel aids and extent of loss of sensation, on 4' wide by 6' long ramps, having a slope of 1:12, the steepest slope normally permitted for ramps. This was therefore a very conservative test, intended to obtain information regarding the impact of detectable warnings on the steepest permissible slopes, not just on those persons who are the most active, independent travelers, but also on persons whose disability, aid and/or stamina makes all travel difficult. Participants were deliberately recruited whose aids and or disabilities had been mentioned by persons with disabilities and their advocates as likely to experience difficulties with detectable warnings.

Persons with physical disabilities were videotaped as they negotiated up and down each ramp having detectable warnings, as well as a comparison ramp having a brushed concrete surface. While on each surface, participants started, stopped, and initiated a turn, thus performing the range of activities they might have occasion to perform on ramps. After negotiating up and down each ramp, each participant rated that ramp for safety and negotiability relative to the brushed concrete ramp.

Performance on the videotapes was subsequently rated by three raters on a scale developed in consultation with a senior Registered Physical Therapist, in which specific behaviors were rated which are indicative of effort and safety. The rated items differed somewhat according to the aids used. For example, where wheelchairs were used, entrapment of wheels in the truncated domes was rated, as this would result in impaired ability to control the direction of the chair, affecting both ease of negotiation and safety. Where crutches were used, slipping of the tips was rated, indicating decrease in safety.

METHOD

Pilot Study: Negotiability and Safety of Detectable Warning Surfaces on a Level Platform

This pilot study was undertaken to facilitate the choice of the most "useful" surfaces to be tested for safety and negotiability on ramps. It was desirable, overall, to test surfaces which had been shown to be high in detectability and which were also anticipated to be relatively safe and easy to negotiate. However, it was also desired to include surfaces which differed in specific ways, in order to begin to understand the contributions to safety and negotiability of various warning surface attributes. Furthermore, it was desired to test several warning surfaces which appeared to be particularly appropriate for retrofit situations.

In this pilot test, subjective information on perceived safety and ease of negotiability for 13 warning surfaces known to be highly detectable (Bentzen, et al. 1994), was obtained from 11 participants having physical disabilities.

Subjects. Eleven persons with various mobility impairments participated in the study; information concerning participant attributes was obtained during an initial telephone interview and is presented in Table 1. Participants were paid $20.00 for each experimental session. They were recruited through the help of three private and public agencies who serve the needs of persons with disabilities, and by mailings to paratransit users of the MBTA.

Participants were sought who represented a range of mobility impairments and degrees of loss of sensation, as well as a range of mobility aids (e.g., wheelchairs, canes, walkers, orthotics). It was desirable to use this non-probability sample to learn whether individuals having particular attributes would have specific difficulties in negotiating easily and safely over warning surfaces which have been shown to be highly detectable by persons with visual impairments.

Table 1.

Matrix of Participant Attributes – Phase IV: Pilot Study

Aid	Age	Sex	Onset early late	Sensation full minimal loss moderate loss severe loss	Orthotics*	Etiology	Comment
Wheel-chairs	24	M	early	full		Cerebral Palsy	power chair
	39	F	early	full		Multiple Sclerosis	manual chair
	41	F	early	full		Polio	power chair
	58	F	late	full		Multiple Sclerosis	scooter
Canes Crutches Walkers	22	M	late	severe	HKAFO	Spinal cord injury	standard walker
	34	F	early	minimal	shoe orthotics	Spina bifida	one underarm crutch
	49	F	early	full		Cerebral Palsy	heavy (15 lb.) rollator walker
	50	F	early	full	KAFO	Cerebral Palsy	quad cane (wide)
	55	F	late	full		unknown	cane

* KAFO = Knee-ankle-foot orthotic
HKAFO = Hip-knee-ankle-foot orthotic

Materials. Human performance testing was conducted on a portion of a laboratory platform constructed by the MBTA for detectability testing (Bentzen et al., 1994). Specifically, testing was conducted on that portion of the level platform having a brushed concrete platform surface adjoined by ten different detectable warning surfaces. (See Figure 1.) In addition, samples of five other warning surfaces which had been installed in the area of the original test platform were also rated for negotiability and safety.

Procedure. Participants were tested individually in approximately one hour sessions. They were told that they would be traveling over a large brushed concrete platform and 10 other surfaces which might be used as detectable warning surfaces on transit platform edges and curb ramps. Participants started approximately four feet from each surface and were told that they were free to maneuver on these surfaces in any way that they wished to, but including starting, stopping and turning on each surface. They were given as much time as desired to complete this task. After maneuvering on each of the 10 surfaces adjoining the brushed concrete platform, participants maneuvered on each of the five detectable warning surfaces installed on the floor near the platform.

After maneuvering over each warning surface, participants were asked to rate that surface relative to travel on brushed concrete for negotiability (ease of travel) and safety. Ratings were made on a five point scale, ranging from 1 to 5, for both negotiability and safety. A score of 1 for negotiability meant that the surface was as easy to travel over as a brushed concrete surface; a score of 5 meant that the surface was much more difficult to travel over than a brushed concrete surface. Similarly, a score of 1 for safety meant that participants felt as safe traveling over the warning surface as they felt traveling over a brushed concrete surface, and a score of 5 meant that they felt much less safe on the warning surface than on a brushed concrete surface.

Along with their ratings, participants were asked several open ended questions concerning their ease of travel and safety on the warning surfaces on the level platform, as well as on a hypothetical sloped surface.

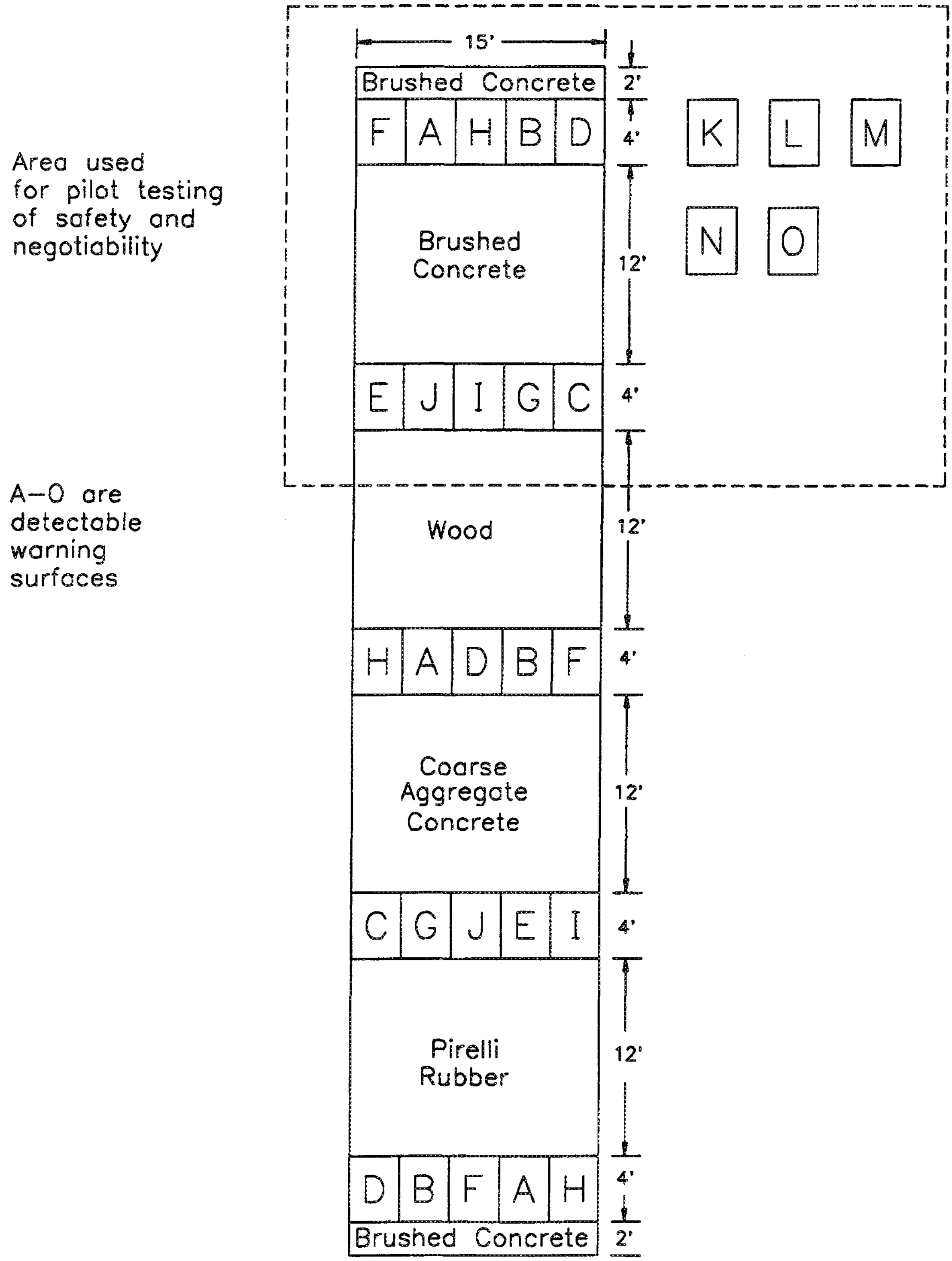


Fig. 1 - Laboratory platform for testing detectability of ten detectable warning surfaces when approached from four platform surfaces. Figure shows portion of platform and adjoining level floor, used for pilot testing of safety and negotiability. Constructed at old Broadway Station, MBTA.

Along with their ratings, participants were asked several open ended questions concerning their ease of travel and safety on the warning surfaces on the level platform, as well as on a hypothetical sloped surface.

At the end of the testing session participants were asked to choose the "three best" warning surfaces for curb ramps, and also to choose the single one they thought would be "best" on a curb ramp. They were also asked if there were any of the warning surfaces that they thought should definitely not be used on a curb ramp.

Negotiability and Safety of Detectable Warnings on Slopes

In this phase, both objective and subjective measures of negotiability and safety of detectable warnings on slopes were obtained from 40 persons with physical disabilities.

Subjects. Forty persons with physical impairments participated in this study. Participants were paid $20.00 for each experimental session. They were recruited through six public and private agencies which serve the needs of persons with physical impairments, and by mailings to MBTA paratransit riders.

Participants were purposefully sought who represented a wide range of attributes of persons who are physically disabled and who travel regularly and independently in the environment. It was desirable to use this non-probability sample to learn whether individuals having particular attributes are affected in their ability to negotiate easily and safely over detectable warning surfaces applied to ramps. The variables of most interest and concern were mobility aid used, amount of sensation, and cause of impairment. Table 2 is a matrix of participant attributes. Over-represented in the group were participants who were severely impaired or who were anticipated to be particularly likely to experience difficulty traveling over the bumpy detectable warning surface.

Table 2.

Matrix of Participant Attributes: Phase V

Aid	**Age**	**Sex**	**Onset** early late	**Sensation** full minimal loss moderate loss severe loss	**Orthotics***	**Prosthetics**	**Etiology**	**Comment**
	10	F	early	full			cerebral palsy	Zippy chair mother pushed
	26	M	late	severe			spinal cord injury	Quickie GPV (quadriplegic)
	29	F	late	full			multiple sclerosis	standard manual chair
	36	M	early	full			arthritis; scoliosis	Quickie chair
	56	M	late	minimal			spinal cord injury	Quickie II chair (paraplegic)
	37	M	late	full			spino-muscular atrophy	power chair
Wheels	41	F	early	minimal			polio	power chair
Wheel-chairs	45	F	early	full			spinal cord injury	power chair
Scoo-ters	48	M	early	full			centro-nuclear myopathy	power chair
	52	M	late	severe			spinal cord injury	power chair
	56	F	late	full			bilateral amputee	power chair
	47	M	early	full			cerebral palsy	power chair w/ foot control
	41	M	late	moderate			multiple sclerosis	4-wheel scooter
	52	M	late	full			spinal cord injury	3-wheel, rear drive scooter

	58	F	late	full			multiple sclerosis	3-wheel, rear drive scooter
	37	M	late	severe		below knee	accident	cane
	47	F	late	full	AFO (rt. foot)		stroke	cane
	51	F	late	full	AFO (rt. foot)		stroke	cane
	53	F	late	severe		bilateral below knee	accident	2 canes
	68	F	late	full			arthritis	cane
	70	F	late	moderate	in shoes		arthritis	cane
	70	F	late	moderate			spinal stenosis; stroke	cane
	50	F	early	full	KAFO both legs		cerebral palsy	narrow-based quad cane
Tips	34	F	early	minimal	molded shoe braces		spina bifida	1 under-arm crutch
canes crutches	43	F	late	full			accident	2 under-arm crutches
walkers	55	M	early	full			muscular dystrophy	2 under-arm crutches
	56	M	early	full			cerebral palsy	2 under-arm crutches
	26	M	early	full			cerebral palsy	Canadian crutches
	29	M	late	full			spinal cord injury	Canadian crutches
	46	M	early	moderate			Charcot Marie-Tooth disease	Canadian crutches
	28	M	late	severe	HKAFO		spinal cord injury	standard walker
	49	F	early	full			cerebral palsy	heavy rollator walker (15 lbs.)
	80	F	late	full			stroke	light rollator walker
	32	M	late	minimal	AFO		accident	
No Aid	32	M	late	severe	AFO		gun shot wound	
	45	M	late	severe		below knee	land mine	
	51	M	late	severe		ankle-foot	gun shot wound	

	19	F	early	full			unknown	
	38	F	early	full			cerebral palsy	
	71	F	late	moderate			poor circulation	

* AFO = Ankle-foot orthotic
KAFO = Knee-ankle-foot orthotic
HKAFO = Hip-knee-ankle-foot orthotic

Steering Committee members, Project ACTION staff, and the physical therapist consultant (L.Desmarais, RPT) to this project all considered that the range of participants adequately represented most persons with physical disabilities who traveled on public transit, as well as a number of other persons whose travel was likely to be more limited. Twenty participants were male and 20 were female; the mean age was 46 years, and the range of ages was 20 to 80 years.

<u>Materials.</u> Human performance testing was conducted on ten adjoining laboratory ramps constructed by the MBTA in an unused portion of a rail rapid transit station. (See Figure 2.) Each ramp was 6' long by 4' wide with a 1:12 slope. Each of nine ramps had a different detectable warning surface applied over the entire 6' x 4' ramp area, and one ramp had a brushed concrete surface. Each of these detectable warning surfaces is depicted on pages 18-21.

Selection of the nine detectable warning surfaces was based on a number of criteria:

- pilot test of safety and negotiability (subjective judgment)
- detectability (Bentzen et al., 19934 (objective and subjective measures)
- input from the Steering Committee
- appropriateness of some surfaces for retrofit applications

In general, pilot data on perceived safety and negotiability of warning surfaces by persons with physical disabilities showed the following. Those surfaces which had been found to be most detectable by persons who are blind (Bentzen et al., 1994) were those that were perceived as most difficult to negotiate, and least safe, by persons with physical disabilities.

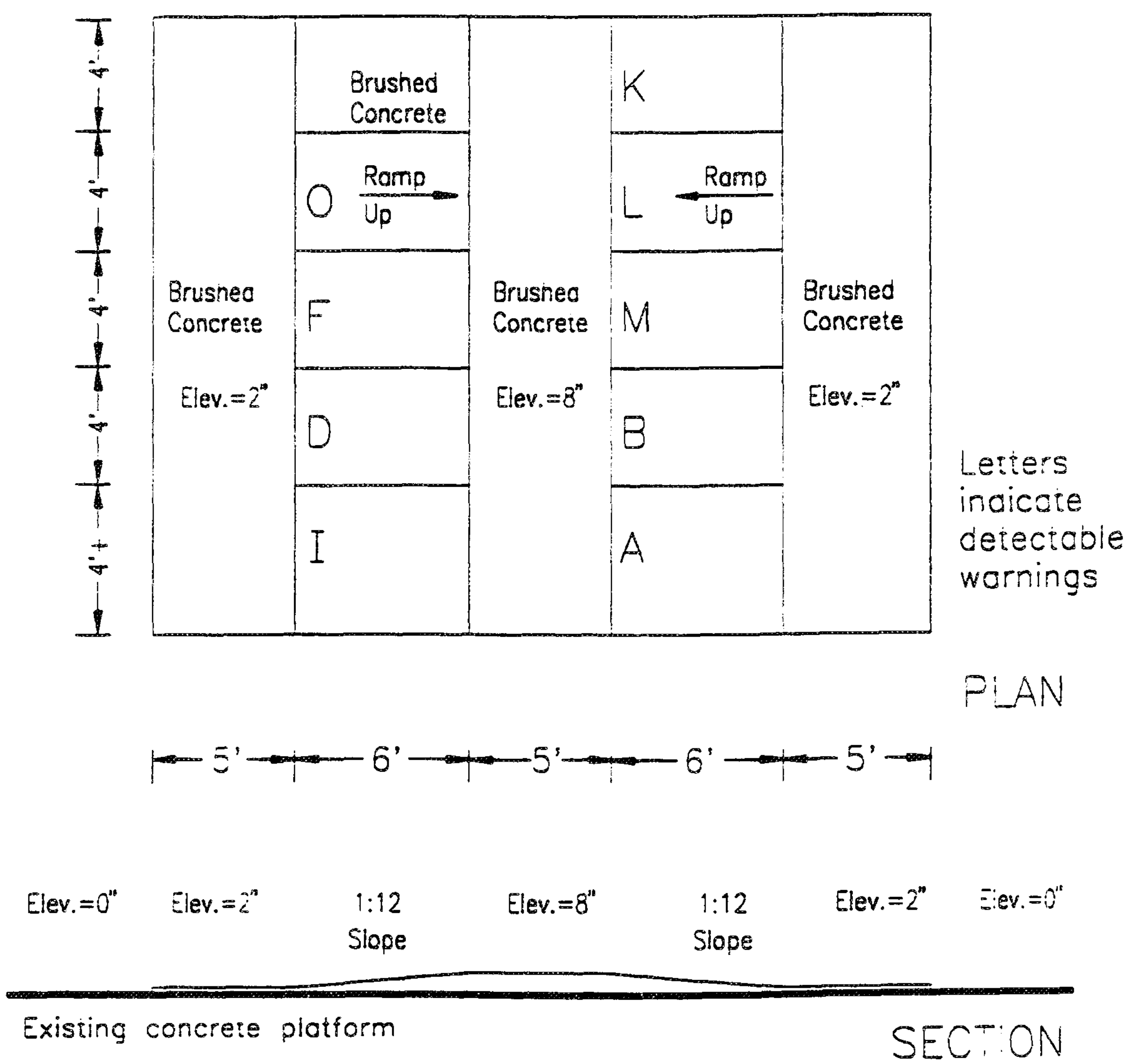
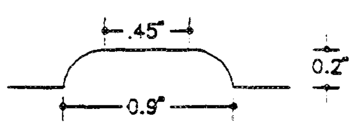
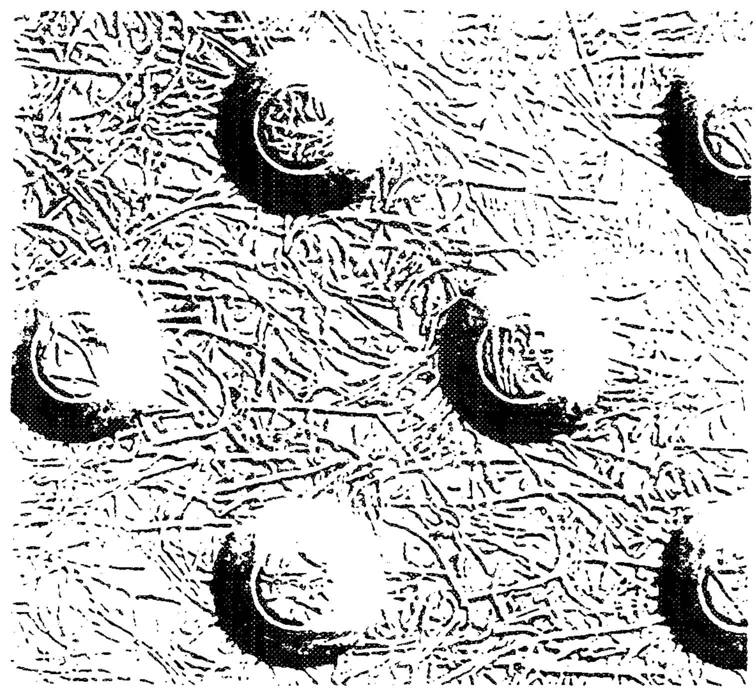


Figure 2. Laboratory ramps for testing safety and negotiability of nine detectable warnings on slopes (1:12). Constructed at old Broadway Station, MBTA.

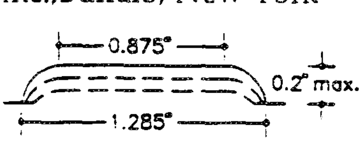
Product A:
Cross-linked thermoset rubber tile, "Pathfinder" -resilient: inconsistent dome spacing between adjacent tiles (domes farther apart).
Carsonite International, Carson City, Nevada

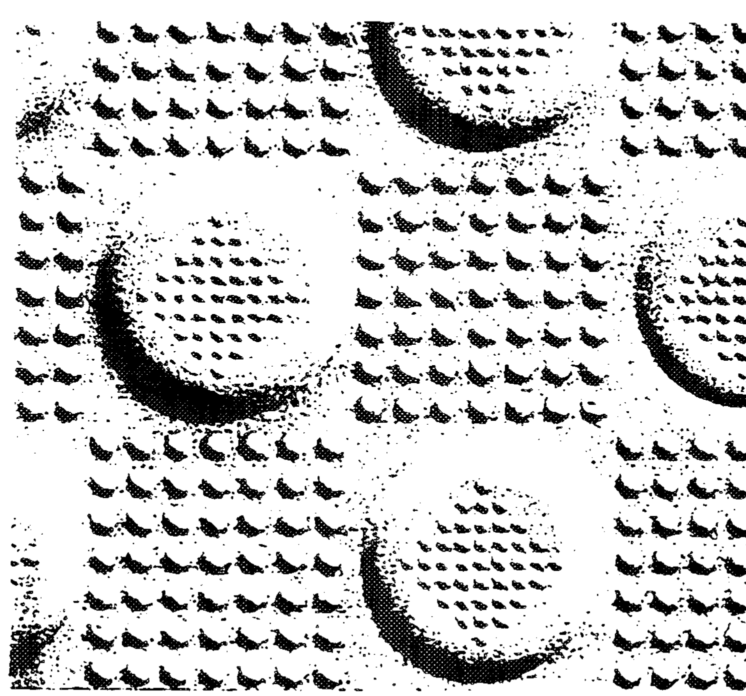
Product B:
Fiberglass reinforced composite,"Pathfinder" -composite; inconsistent dome spacing between adjacent tiles (domes farther apart).
Carsonite International, Carson City, Nevada



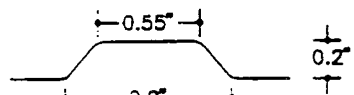


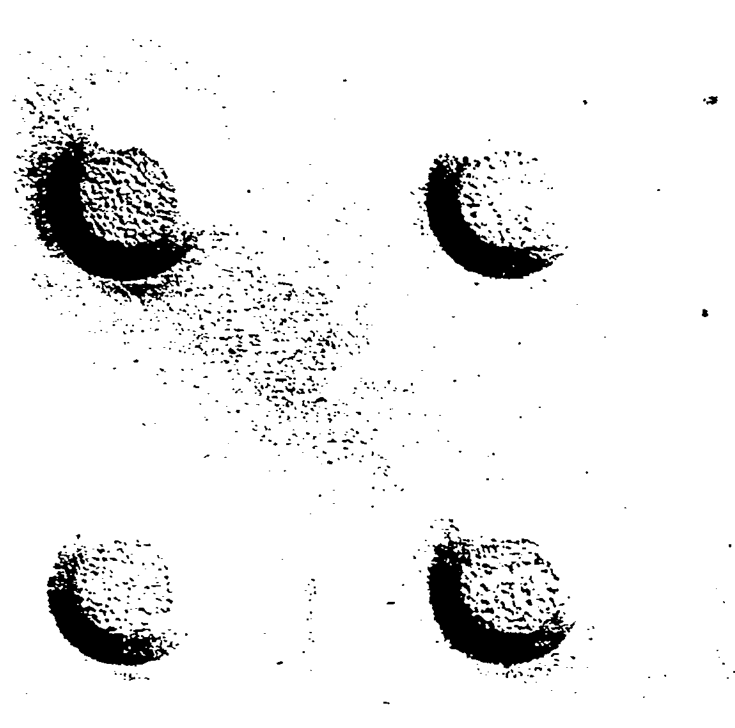
Product D:
Vitrified polymer composite, "Armor-tile"; consistent spacing across adjacent tiles. Domes gradually increase in height & diameter in first 3" of leading edge of tile.
Engineered Plastics, Inc.,Buffalo, New York



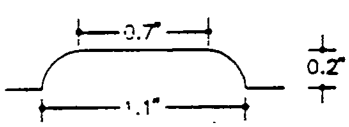


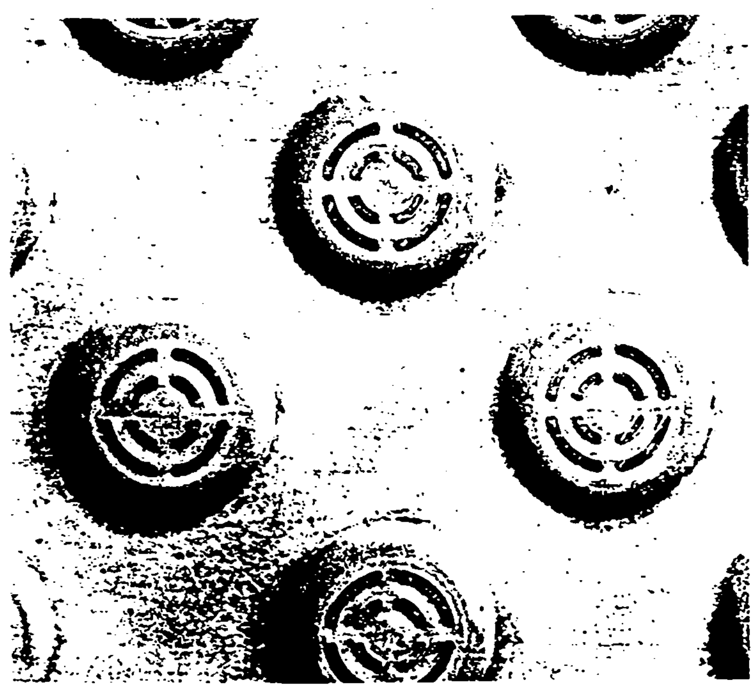
Product F:
Unglazed porcelain tile, "Tactile" - type C; only tested surface with domes aligned on square grid. Consistent spacing maintained across adjacent tiles. Crossville Ceramics, Crossville, Tennesee



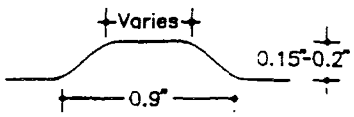


Product I:
Pre-cast polymer concrete, "Step-safe"; consistent spacing across adjacent tiles. Transpo Industries, Inc., New Rochelle, New York



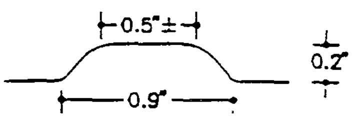


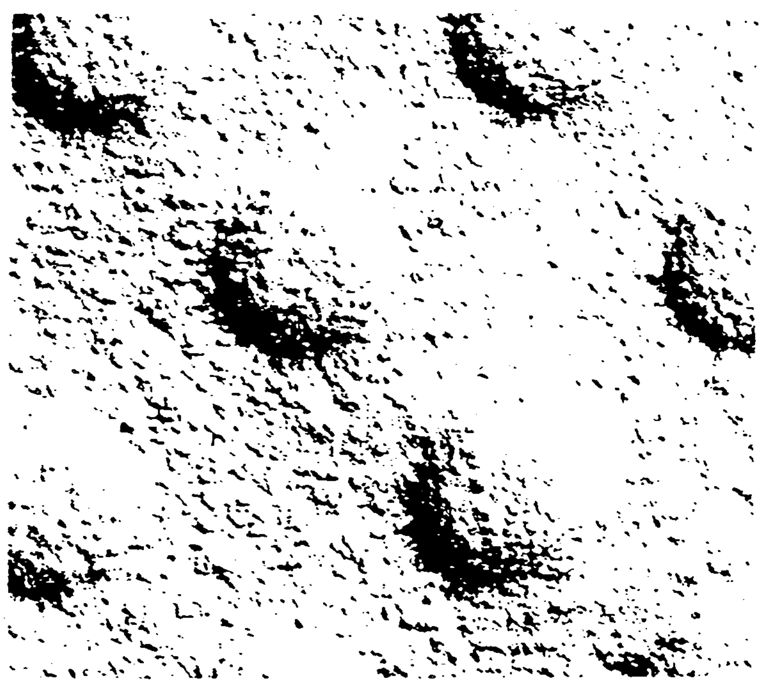
Product K:
Stamped concrete, "Rapidcrete", truncated dome dimensions were inconsistent due to installation difficulties, including sagging of concrete.
Rapidcrete, Inc., Syracuse, New York



sample not available

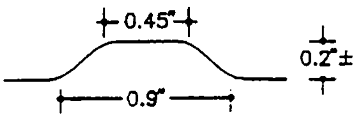
Product L:
Flexible non-skid coating over polyurethane domes, "Safti-trax";
COTE-L Enterprises, Teaneck, New Jersey

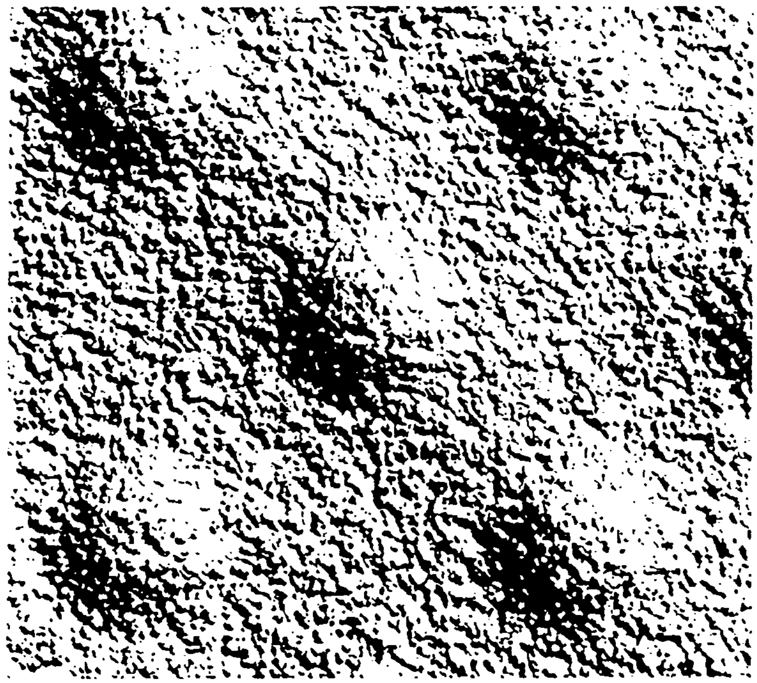




Product M:
Stamped metal with epoxy-type non-slip coating, "Metal Tactile Panel"; has rubberized membrane underneath. Advantage Metal Systems, Brockton, Massachusetts

Product O:
Stamped metal with non-slip co-polymer coating, "Tac Strip"; High Quality Manufacturing, Woburn, Massachusetts





The nine detectable warnings were chosen as follows:

Surface A. Research on this surface was the basis for the ADAAG specifications. It is highly detectable (Bentzen et al., 1994) and subjective judgments in the pilot test rated it intermediate in safety and negotiability.

Surface B. The surface configuration of this surface is identical to that of Surface A, but Surface A was resilient and Surface B was non-resilient. Some differences between the two surfaces could be observed in both objective testing and subjective ratings. Subjective data on negotiability and safety from participants who have physical impairments showed that surface B placed in the top five of surfaces easiest and safest to negotiate, while surface A did not rate quite as highly. Analysis of the detectability data, collected from participants who are visually impaired, showed that there was no significant difference between these two materials in terms of detectability and stopping distance. However, subjective ratings from participants who are visually impaired suggested that people found the resilient surface to be much more detectable than the non-resilient.

[Inclusion of both surfaces A and B in testing safety and negotiability was needed to determine whether differences in resiliency of otherwise similar surfaces affect human performance. If human performance is affected, this implies that products having similar dimensions, but differing in resiliency, cannot be assumed to be equal in safety and negotiability, but must be subjected to independent testing.]

Surface D. Analysis of the subjective ratings from participants with physical impairments showed this surface, having relatively large domes with additional texture elements, to be perceived as one of the least negotiable and least safe. However, both objective and subjective data confirm this surface as one of the most detectable warning surfaces. Because of this conflict, it was important to subject this surface to performance testing on ramps in order to corroborate, by objective testing, the subjective judgments by persons with physical impairments that this surface would cause difficulties in negotiability and safety .

Surface F. This tile surface was the only one tested for detectability on which the domes were aligned horizontally and vertically and not diagonally. It had been demonstrated to be highly detectable (Bentzen et al., 1994). This dome alignment might or might not have particular advantages for persons with physical impairments. For example, wheels may either ride more smoothly, or they might get trapped between the domes, making wheelchair control more difficult. The subjective data from participants with physical impairments indicated that this tile was perceived to be negotiable and safe.

Surface I. This polymer concrete surface having relatively large domes, was judged by participants with physical impairments to be the easiest to negotiate as well as the safest. Objectively, participants with visual impairments had found it to be detectable (Bentzen et al., 1994).

Surface K. This is a stamped concrete surface designed for retrofitting over concrete, on which neither detectability data nor subjective ratings were available at the time the surfaces were chosen for testing on ramps. However, the concept of concrete stamping appeared to have considerable appeal from the aspects of cost and anticipated ease of installation. Therefore, it was desired to obtain objective measures of safety and negotiability. (Subsequent detectability testing indicated that Surface K was highly detectable--Bentzen et al., 1994).

Surface L. This applied resilient surface was selected primarily because of its ease of installation and its applicability in retrofit situations. Participants with physical impairments did not judge this surface to be very negotiable or safe. Subjectively it was judged to be moderately detectable and safe by participants with visual impairments. (Subsequent objective detectability testing indicated that Surface L was highly detectable--Bentzen et al., 1994).

Surface M. This abrasive-coated steel surface was judged as one of the most negotiable and safe surfaces by participants having physical impairments. It was subjectively judged as moderately detectable and safe by participants with visual impairments. (Subsequent objective detectability testing indicated that Surface M was highly detectable--Bentzen et al., 1994). Surface M was of interest particularly for retrofit situations, because it is quite thin, and for application over bases which are not totally flat, because it is somewhat flexible.

Surface O. This surface was descriptively and visually the same as Surface M, but the subjective ratings of safety, negotiability and detectability were different. Surface O was judged as less negotiable and less safe than Surface M by participants with physical impairments, and as less detectable and less safe by participants with visual impairments. No detectability testing was done on this surface.

In this study, subjective measures (i.e., participants' ratings) of negotiability and safety were obtained, and participants' actual performances negotiating these surfaces were videotaped for analysis. Video analysis was based on an objective rating procedure designed to assess safety and ease of travel over these surfaces.

As no rating scale could be located in the literature, a major undertaking of this project was the development of a rating scale which captured differences in performance which were indicative of ease of negotiation and of safety, both between participants and between surfaces. This task was accomplished with input from Linda Desmarais, R.P.T., consultant to this project, and was piloted with the assistance of persons with physical disabilities at Boston College, on ramps at Boston College.

The rating scale varied for each category of aid ("No aid," "Wheels," and "Tips"), taking into account the different issues that arise with different aids. The "No aid" group consisted of people who had balance problems, and/or who wore orthotics or prostheses. The "Wheels" group consisted of people who used power wheelchairs, manual wheelchairs, or scooters. The "Tips" group consisted of people who used canes, crutches, or walkers, including rollator walkers. A copy of the rating scale is shown in Appendix A. The various aids used were as follows:

<u>Wheels</u>

Power wheelchair:	(5) non-pneumatic tires
	(1) pneumatic tires
	(1) non-pneumatic tires, foot control
Manual wheelchairs:	(1) standard, non-pneumatic tires
	(3) light weight (Quickie II)
	(1) sport (Quickie GPV)
Scooters:	(2) 3-wheeled scooters - rear wheel drive
	(1) 4-wheeled scooter - rear wheel drive

<u>Tips</u>

Crutches:	(1) single underarm
	(3) double underarm
	(3) Canadian
Canes:	(6) single, standard canes

	(1) double canes (person used 1 in each hand) (1) quad cane
Walkers	(1) standard aluminum (2) rollator (one heavy (14 lbs) one light)

No Aid

None:	(3)
Orthotics:	(2) ankle-foot
Prostheses:	(1) right, below knee, Betello weight-bearing with a flex-walk foot (1) left AK, Silesian belt, Seattle foot

Procedure. Participants were tested individually in sessions lasting approximately one hour. Participants were told that they would be traveling up and down 10 ramps, one of which had a brushed concrete surface and nine of which had different detectable warning surfaces. The procedure for testing negotiability and safety on the ramps was as follows.

The brushed concrete ramp, which served as a control surface, was traveled over at the beginning and again half way through the session, so that participants could rate the warning surfaces relative to the brushed concrete. This also provided video raters with more than one sample of performance on brushed concrete for comparison with performance on the detectable warnings. The procedure was explained and demonstrated to each participant, using the first trial on the brushed concrete ramp.

Participants began on a level concrete platform five feet from the bottom of each ramp. They traveled straight ahead onto the ramp, and when they had traversed two feet onto the ramp surface (denoted by a black line going the full width of each surface) they stopped, waited approximately three seconds and then continued up the ramp. After traversing four feet onto the ramp surface (again, denoted by a black line going the full width of each surface) participants began to initiate a turn, which they completed at the top of the ramp, on a brushed concrete landing. They waited approximately five seconds at the top of the ramp (longer if they requested a slower pace), then descended, stopping briefly after traveling four feet down the ramp, then continuing straight down to the level concrete platform at the bottom of the ramp. Each participant completed a minimum of two initial practice trials on the brushed concrete ramp, to be sure that all instructions were understood, before beginning the experimental trials. Each trial was videotaped, including all trials on the brushed concrete ramp.

The order of testing of the nine different warning surfaces was randomized within the two sets of ramps, one set on each side of the central concrete aisle. (See Figure 2.) The order of these two sets was counterbalanced.

Following travel up and down each ramp, participants rated that ramp for ease of negotiability and safety relative to the brushed concrete ramp. Ease of negotiability was defined as, "the effort required to travel over the surface – starting, stopping, going up, going down, and turning on the surface material." Safety was defined as, "whether you feel insecure - like you may fall, slip, tip over, trip, or otherwise become harmed while traveling over the surface." Participants were periodically reminded to make each rating relative to their ease of travel and safety while traveling up and down the brushed concrete ramp. Ratings were made on a five point scale, ranging from 1 to 5 for both negotiability and safety. A score of 1 for negotiability meant that the warning ramp was as easy to negotiate as the brushed concrete ramp, and a score of 5 meant that the warning ramp was much <u>more</u> difficult to negotiate than the brushed concrete ramp. For safety, a 1 meant that the warning ramp was as safe to travel over as the brushed concrete ramp, and a 5 meant that the warning surface was perceived as much less safe to travel over than was the brushed concrete ramp.

After completing the entire session participants were asked which three surfaces, of the nine warning surfaces that they had traveled over, they would choose for use on curb ramps, which surface they liked "best" for use on curb ramps, and which surface or surfaces "should not be used on curb ramps."

A Registered Physical Therapy Assistant was present at all times and shadowed participants throughout the entire experiment to ensure the safety of participants against the danger of falling. Participants were encouraged to rest as often as they desired, and given the option of not negotiating ramps that looked "too difficult or unsafe" to them. In addition, if participants appeared excessively tired, they were encouraged not to negotiate all the ramps. If they were too tired, they were not required to negotiate all ramps. Despite these options given to participants, only two participants did not complete all the ramps; these persons each failed to complete the negotiation of just two ramps having detectable warning surfaces.

RESULTS AND DISCUSSION

Objective measures of safety and negotiability

Each videotaped trial (in which an individual traveled up and down one ramp, starting, stopping and turning on the warning surface) was viewed and rated by three independent raters, using a scoring sheet developed for the purpose. Depending on which travel aid was used, "no aid," "wheels" (power and manual wheelchairs and scooters), or "tips" (canes, crutches and walkers, including rollator walkers), the scoring sheet required observation and rating of from three to seven behaviors, such as "effort required to start from stop," "stability," and "wheels slip." (See Appendix A). Some behaviors were rated separately for the trip up the ramp and the trip down. Each behavior received either a "0" or a "-1", depending on whether the rater judged that the participant had difficulty equal to that when traveling on a brushed concrete ramp (0), or greater difficulty (-1).

With 40 participants, nine ramps with detectable warning surfaces, and either three or seven observed behaviors per ramp per participant (depending on type of aid), there were a total of 2,268 behaviors observed and rated by each rater. Overall reliability was excellent: all three raters agreed on 89.5% of all ratings, and at least two out of three raters agreed on 92.9% of all ratings.

It was not possible to separate safety and negotiability in analyzing the data obtained, as a majority of the behaviors observed could be reflective of either or both decreased negotiability and decreased safety. For example, if wheels or tips became entrapped in domes, greater effort might be required to control the direction of travel (decreased negotiability), and a decrease in ability to control direction could result in decreased safety. The distinction between negotiability and safety impacts of wheel or tip entrapment would have been too subjective to be reliable. Therefore, raters observed only, e.g., whether wheels or tips became entrapped. They did not speculate further on whether this resulted in decreased negotiability or decreased safety. All ratings of -1 are therefore simply reported as observed difficulties.

Of the 2,268 rated behaviors, raters were unanimous in observing no difficulties for 88.5% of all rated behaviors. However, on 258 rated behaviors (11.5%) difficulties were observed by one or more raters, indicating some degree of difficulty in negotiability or safety, which was greater than that observed for travel on brushed concrete.

Agreement on observed difficulties was not as good as for observations of no difficulty. Of 262 observed difficulties, 160 (61%) were observed by only one out of three raters, and only 20 (8%) were observed by all three raters. The low agreement on observed difficulties can be accounted for in two ways. First, there were relatively few observed difficulties overall, and the fewer the observations or ratings (of any sort) the more difficult it is to achieve high levels of inter-rater reliability.

Second, and perhaps more important to understanding the implications of this research, for many participants, travel under any circumstances is a challenge. The sample was deliberately biased toward inclusion of participants who were expected to have difficulties with detectable warnings. Persons with minimal physical disabilities, who comprise the largest group of persons who are physically impaired, were represented by only a few individuals in this project. It was difficult to standardize the determination of what constituted **additional** difficulties beyond what were normal for an individual participant who might, for example, be observed to travel on the brushed concrete ramp with great effort and instability.

Because of the difficulty of achieving agreement on observed difficulties, they were counted in two different ways. When the "number of observed difficulties" is reported for a given participant on a given surface, that number does not reflect interrater agreement; it is simply a count of any difficulties that any (or all) of the raters observed. In order to provide a measure that does reflect agreement (and thus perhaps extent of difficulty), we also report a "score"; the "score" for a given participant on a given surface is the sum of all observed difficulties added across all raters. For example, suppose a participant was observed to have two difficulties (e.g. wheels slip, and increased effort) on surface A, by only one rater. The "number of observed difficulties" would then be two, and the "score" would also be two. If all three raters observed those same difficulties, however, the "number of observed difficulties" would still be two, but the "score" would be six.

Because of obvious differences in travel difficulty and types of problems, data were analyzed in groups according to type of travel aid ("no aid", "wheels", or "tips"). Furthermore, participants fell roughly into three categories: those with no scored travel difficulty, those with relatively few travel difficulties (average score per surface ranged from 0.2 to 1.3), and those with numerous difficulties (average score per surface ranged from 2.3 to 6.8, with the exception of one borderline case averaging 1.8). These data are summarized in Table 3.

Table 3.

Participants Grouped by Travel Aid and Amount of Difficulty

	# subjects	mean score per surface
No aid n = 7		
No difficulty	4	-
Few difficulties	3	0.6
Numerous difficulties	0	-
"Wheels" n = 15		
No difficulty	5	-
Few difficulties	6	0.5
Numerous difficulties	4	3.6
"Tips" n = 18		
No difficulty	5	-
Few difficulties	10	0.9
Numerous difficulties	3	4.7

Fourteen of 40 participants (35%) showed no difficulties. Nineteen participants (47.5%) showed few difficulties, and seven (17.5%) were observed to have numerous difficulties across most or all of the surfaces. These seven participants accounted for 153 (59%) of the total 262 observed difficulties. Not surprisingly, interrater agreement on observed difficulties was best for those participants who had numerous difficulties, indicating that these participants represent the unambiguous cases.

The seven participants who accounted for 59% of all observed difficulties, and on which there was good interrater agreement are described below.

Of the seven participants who accounted for 59% of all observed difficulties, and on whom there was good interrater agreement, four traveled using manual wheelchairs, two used rollator walkers, and one used a quad cane. Three of those four participants who used manual wheelchairs had Quickie chairs, characterized by very small diameter front wheels. They were all three very strong, active travelers, used to negotiating bumpy surfaces. While the detectable warnings caused some wheel slippage and entrapment, as well as apparently increased effort relative to brushed concrete, all of these three travelers appeared to compensate well for the effects of the detectable warnings.

One participant used a standard manual wheelchair, and finds most ramps (without detectable warnings) to be moderately difficult, primarily as a result of upper body weakness. He also appeared to compensate well for the effects of the detectable warnings, although they required increased effort, which tired him.

The two participants who used rollator walkers use wheelchairs for most outdoor travel. One mentioned that she finds curbs easier to negotiate than curb ramps when using her rollator walker. Both of these participants were too fatigued to complete all ramps having detectable warnings--each one failed to complete performance on two ramps.

The participant who completed the test using a quad cane uses a motorized wheelchair for all outdoor travel. He has knee, ankle and foot orthotics, and coordination difficulties, but was able to complete all travel on all test ramps.

The different kinds of difficulties encountered are presented in detail in Table 4, by travel aid, by surface, and by numbers of participants. For users of "wheels," the most common problem was increased effort starting on the up ramp; less commonly, wheels were occasionally trapped in domes or slipped. For users of "tips," not surprisingly, the most common problem was decreased stability, a problem for which many are already at risk. A number of these participants also showed increased effort starting up ramps, and a few participants showed trapped or slipping tips. One participant was unable to finish surfaces A and L, and another was unable to finish surfaces A and M; both of these participants traveled with the aid of rollator walkers and fatigued easily.

Table 4.

For Each Observed Difficulty, # of Participants Who Had Difficulty, by Surface.

	SURFACE									
Type of difficulty	A	B	D	F	I	K	L	M	O	**Total**
No aid										
UP: effort	-	-	-	-	-	-	1	-	-	1
stability	1	-	-	-	-	1	2	-	-	4
DOWN: stability	-	-	-	1	-	-	2	-	1	4
"Wheels"										
UP: effort	4	5	4	1	4	4	3	5	3	33
stability	-	1	-	-	1	-	1	2	1	6
wheels slip	2	4	4	-	1	1	2	2	1	17
wheels trapped	1	2	3	-	2	2	2	3	1	16
DOWN: stability	-	-	-	-	1	-	-	1	-	2
wheels slip	-	3	6	-	2	1	-	1	1	14
wheels trapped	1	3	3	-	1	1	1	1	1	12
"Tips"										
UP: effort	2	4	5	1	5	3	4	4	4	32
stability	5	4	4	3	6	1	8	2	6	39
aid slips	-	1	1	-	1	-	-	1	-	4
aid trapped	-	2	2	1	3	3	2	2	3	18
DOWN stability	5	8	6	3	5	2	6	5	1	41
aid slips	-	1	-	-	1	2	-	-	-	4
aid trapped	-	2	2	2	2	2	1	2	2	15

Table 5 gives the distribution of ratings by rater, by surface and by participant. In the main body of the table, each entry consists of three numbers: # difficulties observed by rater 1/# difficulties observed by rater 2/# difficulties observed by rater 3. There are substantial differences according to total score per surface. Chi-square tests confirmed that, for users of "wheels", surface F had a significantly lower score (1X9 chi-square = 38.06, $p<0.01$). When surface F is excluded from the analysis, surface K also had a significantly lower score (1X8 chi-square = 18.34, $p<0.05$) than the other surfaces, and surfaces D and B had significantly higher scores (1X8 chi-square = 18.34, $p<0.05$). For users of "tips", surfaces F and A had significantly lower scores, and I and B had significantly higher scores (1X9 chi-square = 21.21, $p<0.05$).

Excluding from the analysis the seven participants with numerous difficulties across nearly all surfaces, these findings are quite different. Among users of "wheels" the only finding is that surface D had a significantly higher score (1X9 chi-square = 37.09, $p<0.01$); among users of "tips" there were no significant differences, although the finding that surface K had a lower score (1X9 chi-square = 14.26, $p<0.09$) is nearly significant.

Table 5.

<u>Raters' Scores by Subject and Ramp (# Observed Difficulties, Rater 1/Rater 2/ Rater 3)*</u>

	RAMP									
Subject #	A	B	D	F	I	K	L	M	O	score
"No aid"										
3	-	-	-	-	-	-	2/-/-	-	-	2
11	-	-	-	-/1/1	-	3/-/1	-/1/2	-	1/1/1	12
12	-	-	-	-	-	-	-	-	-	-
20	-/-/1	-	-	-	-	-	-	-	-	1
28	-	-	-	-	-	-	-	-	-	-
35	-	-	-	-	-	-	-	-	-	-
37	-	-	-	-	-	-	-	-	-	-
Subtotal Score	1	-	-	2	-	4	5	-	3	15
"Wheels"										
6	1/-/2/	4/-/3	2/-/1	-/-/1	1/1/1	1/-/1	-/-/1	-/-/3	1/-/1	25
8	-	-/-/1	1/-/-	-	-	-	-	-/-/2	-	4
10	-	1/-/-	4/-/-	-	-	-	-	-	-	5
13	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-
24	1/1/-	1/1/-	3/1/1	-	1/1/-	-	-/1/-	1/1/1	1/-/-	16
25	-	-	-	-	-	-	-	-	-	-
27	1/3/2	1/3/2	-	-	3/4/-	1/3/-	4/4/1	3/3/2	5/4/1	50
29	-	-	-	-	-	-	-	-	-	-
30	-	1/-/-	-	-	1/-/-	1/-/-	-	-	-	3
33	-/1/1	4/3/2	3/3/2	-	4/3/3	1/1/-	-/1/2	3/2/-	-	39
36	-	-	-	-	-	-	1/-/-	-	1/-/-	2
38	-	-	2/-/-	-	-	-	-	-	-	2
40	-	2/-/-	5/-/-	-	-	-/-/2	-	1/-/2	-	12
Subtotal Score	13	29	28	1	23	11	15	24	14	158
"Tips"										
1	-	-	-	-	-	-	-	-	-	-
2	1/-/-	-/-/1	-/-/1	-	1/-/1	1/-/-	-	2/1/-	-	9
4	-	-	-	-	-	-	-	-	-	-
5	-	1/-/-	-	-	-	-	1/1/1	-	1/-/-	5
7	-	-	1/-/-	-/-/1	-	-	2/-/-	-	-	4
9	-	-	-	-	-	-	-	1/1/-	-/1/1	4
14	**/1/1	7/2/3	6/2/3	2/-/1	6/2/3	5/2/1	**/2/1	3/1/-	1/3/3	61
15	1/-/2	1/-/1	3/-/2	-/-/1	3/-/-	1/-/-	1/-/1	1/-/-	1/-/2	21
16	-	-	-	-	-	-	-	-	-	-
17	-	1/-/-	-/-/1	-/-/1	-	-	-	-/2/1	-	6
18	-	-	-	-	-	-	-	-	-	-
19	2/-/1	2/-/-	-	1/-/2	-	-	2/-/-	2/-/-	-	12
21	2/-/-	2/-/1	2/-/-	-	2/-/-	-	2/-/-	-	1/-/-	12
26	-	-	-	-	2/-/-	-	-	-	-	2
31	-	-	-	2/2/-	3/-/2	1/-/-	-	1/-/-	-	11
32	-	-	-	-	-	-	-	-	-	-
34	2/-/-	1/-/-	2/-/-	-	2/-/1	-	2/-/-	2/-/-	-	12
39	**	5/-/3	3/-/3	1/-/-	4/-/3	4/-/3	5/-/3	**	4/-/3	44
Subtotal Score	13	31	29	14	35	18	24	18	21	203

* e.g., S 6 traveled with the aid of wheels. On surface I, each of 3 raters observed 1 difficulty; on surface D, rater 1 observed 2 difficulties, rater 2 observed no difficulties, and rater 3 observed 1 difficulty.
** Incomplete.

Subjective measures of safety and negotiability.

Ratings. Participants rated each surface on a 5 point scale, for ease of negotiability and for safety, relative to brushed concrete. (1 = as easy or safe as brushed concrete; 5 = much more difficult or much less safe than brushed concrete.) Ratings were collected and analyzed within each of the three groups of travel aids. Mean ratings are given, with surfaces ranked from best to worst, in Table 6. Separate within-subjects ANOVA's for the ratings from each travel aid group were computed.

Table 6.

Mean Ratings of Ease and Safety, by Travel Aid, With Surfaces Listed in Left Column and Ratings Listed in Right.

No aid				"Wheels"				"Tips"			
Ease		Safety		Ease		Safety		Ease		Safety	
I	2.0	I	2.0	F	1.6	F	1.6	I	2.1	I	2.0
K	2.1	D	2.1	M	2.3	A	1.8	F	2.2	K	2.1
A	2.2	K	2.3	A	2.35	L	1.9	K	2.3	F	2.3
B	2.35	A	2.4	L	2.4	M	2.0	M	2.45	A	2.5
D/L	2.4	B/L	2.5	I	2.45	I	2.1	O	2.5	O	2.55
D/L	2.4	B/L	2.5	O	2.5	B	2.3	A/D	2.7	D	2.6
F/M	3.1	F/M	3.4	K	2.7	D	2.5	A/D	2.7	B	2.7
F/M	3.1	F/M	3.4	B	3.1	O	2.55	B	2.75	M	2.9
O	3.6	O	3.6	D	3.2	K	2.6	L	2.8	L	3.1

For the group of participants who traveled with "no aid", ratings differences between surfaces were significant for both ease, ($F(8,48) = 2.16$, $p<0.05$), and for safety, ($F(8,48) = 2.12$, $p<0.05$). On the basis of the Newman-Keuls procedure, the surfaces may be divided into two groups with significantly different ratings: surfaces I,K,A,B,D, and L were rated relatively easy and safe to negotiate, and surfaces F,M,O were rated relatively difficult and unsafe.

For the group of participants who traveled with "wheels", differences in ratings were highly significant for both ease, ($F(8,112) = 5.28$, $p<0.0001$), and for safety, ($F(8,112) = 3.57$, $p<0.001$). On the basis of the Newman-Keuls procedure, the ratings for ease of travel indicate that surface F was rated significantly better than any of the other surfaces. The ratings for safety were less conclusive, but the Newman-Keuls procedure indicated that surface F was rated significantly safer than surfaces D, O, K.

For the group of participants who traveled with "tips", there were no significant differences in ratings of the surfaces for ease of travel or safety.

To summarize, the surface ratings show different and in some respects contradictory patterns for different groups of participants. In particular, surface F was rated by users of "wheels" as very nearly equivalent to brushed concrete for ease of travel and safety, and clearly superior to the other surfaces; yet, those participants who use "no aid" rated surface F as among the worst with respect to both ease and safety. (There was, however, only one observed difficulty on surface F for all participants using "no aid.")

Preferences. In addition to rating the nine surfaces for ease and safety, participants also expressed preferences by selecting the "three best", "single best", and any number of surfaces that "should not be used at all" from among the surfaces. Totals are given in Table 7 for each travel aid group. Note that surfaces that received equal preference scores are grouped together and repeated across adjacent rows.

For the group of participants who traveled with "no aid", a chi-square analysis indicated that there were no significant differences among preferences.

For the group of participants who traveled with "wheels", the preference for surface F in the categories "three best" (1X9 chi-square = 19.27, $p<0.02$) and "single best" (1X9 chi-square = 24.17, $p<0.001$) was significant. The preference against surface D (1X9 chi-square = 16.63, $p<0.05$) was also significant. These preferences conform well to the group's ease and safety ratings.

For the "tips" group, the preference for surfaces I and K in the "three best" category (1X9 chi-square = 25.44, $p<0.001$) was significant, as was the preference for surfaces F, I, and K in the "single best" category (1X9 chi-square = 17.63, $p<0.05$). These preferences mirror the ratings scores from this group, although the ratings differences were not statistically significant. There were no significant preferences in the "worst" category.

Table 7.

Surface Preferences, Ordered from Highest to Lowest (# Subjects Choosing Each Surface).

"No aid"			"Wheels"			"Tips"		
Three best	Single best	Un-usable	Three best	Single best	Un-usable	Three best	Single best	Un-usable
K (4)*	K (2)	F (3)	F (12)	F (6)	D (6)	I (11)	I (4)	O (8)
A/D/I (3)**	D/L (1)	M/O(2)	D/I(5)	I (2)	B (3)	K (9)	F/K (3)	M (7)
A/D/I (3)**	D/L (1)	M/O(2)	D/I(5)	D/L/M (1)	I/K/O (2)	D/F(7)	F/K (3)	B/D/F /L (4)
A/D/I (3)**	-	B/D/K (1)	K (4)	D/L/M (1)	I/K/O (2)	D/F (7)	D (1)	B/D/F /L (4)
B/L (2)	-	B/D/K (1)	A/L/O (3)	D/L/M (1)	I/K/O (2)	B (4)	-	B/D/F /L (4)
B/L (2)	-	B/D/K (1)	A/L/O (3)	-	-	A (3)	-	B/D/F /L (4)
M (1)	-	-	A/L/O (3)	-	-	M/O (1)	-	A (3)
-	-	-	M (2)	-	-	M/O(1)	-	I (2)
-	-	-	B (1)	-	-	L (0)	-	K (1)

* i.e., 4 participants using "no aid" included surface K in their selection of the "three best" surfaces.

** i.e., 3 participants using "no aids" included surface A in their "three best," 3 participants included surface D, and 3 participants included surface I.

Comparison of objective and subjective data.

Objective data (ratings of performance observed on videotape) were compared with subjective data (participants' own ratings of, and preferences for, surfaces) to determine whether the subjective data could be used alone to provide an assessment of the safety and negotiability of detectable warning surfaces that would be comparable to actual performance evaluation.

For the "no aid" group, the sparsity of objective data makes the comparison of objective and subjective data meaningless for this group. These participants did express subjective preferences; however, there were not sufficient observable performance difficulties to make the comparison useful.

For the group of participants who traveled with "wheels", the objective data indicated that surface F, and to a lesser extent surface K, caused the fewest travel difficulties; surfaces B and D caused the most difficulties. The ratings for ease and safety corroborate these findings insofar as they unambiguously select surface F as best; however, they fail to show an advantage for surface K and do not unambiguously show a disadvantage for surfaces B and D. The expressed preferences of this group were for surface F and against surface D, matching the objective data fairly well.

For the "tips" group, the objective data indicated that surfaces F and A caused the fewest travel difficulties, while surfaces I and B caused the most. There were no significant differences in ease or safety ratings. The expressed preferences of this group for surfaces F, I and K coincide with the objective data only in the case of surface F. Note that while surface I was highly preferred, a relatively high number of difficulties were observed on that surface.

These varying correlations between subjective and objective data are not surprising; however, they are somewhat revealing. They are not surprising for several reasons. First, remember that the objective data only reflect the performance of those participants who were rated as having (one or more) travel difficulties on the surfaces. In the objective data, for those participants with no apparent travel difficulties, all surfaces are equally "good". There is no question, however, that these participants often had clear preferences among surfaces, even though for them there may have been no observable performance differences. Second, note that the objective data, when analyzed by observed difficulty or score, effectively give greater weight to the performance of those participants with the greatest travel difficulty (because they contribute more observed difficulties to the analysis). In contrast, the subjective ratings give equal weight to each participant who gives a response.

For the same reasons, the comparison of these data is revealing. First of all, it is clear that even among those users of "wheels" with no travel difficulty, there is a strong preference for surface F. This is an important qualification to the finding that, when those with numerous difficulties are excluded from the analysis, the performance advantage for surface F disappears. For users of "tips", on the other hand, it is the disparity between subjective and objective data that is revealing; for instance, surface I caused the most difficulties and was also one of the most preferred. What this disparity reveals is the fact that the "tips" group was more heterogeneous in terms of performance on and perception of the surfaces. That is why the performance differences become insignificant when those participants with the most numerous difficulties are excluded from the analysis, and also why the ratings and some preferences showed no significant differences between surfaces. It does not necessarily mean that the participants found no differences; it means only that they did not agree on what those differences were.

Combination of Objective and Subjective Data.

It is very difficult to synthesize the results of objective and subjective tests into one simple presentation. However, some kind of synthesis is a necessary aid to understanding the entire body of results. Table 8 presents both objective and subjective data in a simplified form.

Table 8.

Observed Difficulties and Participant Judgments About Safety and Negotiability of 9 Detectable Warning Surfaces on Slopes (1:12, in Comparison With Brushed Concrete).

SURFACE*	A	B	D	F	I	K	L	M	O
Objective Measures** (Observed difficulties)									
Persons Using: **Wheels** n=15	-8	-18	-20	-1	-12	-9	-9	-15	-8
Tips n=18	-12	-22	-20	-10	-23	-13	-21	-16	-16
No Aid n=7	-1	0	0	-1	0	-1	-5	0	-1
Subtotal Objective	**-21**	**-40**	**-40**	**-12**	**-35**	**-23**	**-35**	**-31**	**-25**
Subjective* Measures** (Preference score)									
Persons Using: **Wheels** n=15	+3	-2	0	+18	+5	+2	+4	+3	+1
Tips n=18	0	0	+4	+6	+13	+11	-4	-6	-7
No Aid n=7	+3	+1	+3	-3	+3	+5	+3	-1	-2
Subtotal Subjective	**+6**	**-1**	**+7**	**+21**	**+21**	**+18**	**+3**	**-4**	**-8**
TOTAL SCORE	**-15**	**-41**	**-33**	**+9**	**-14**	**-5**	**-32**	**-35**	**-33**

* Letter designations for surfaces are the same as for tests of detectability, and safety and negotiability.

** Negative values of these scores are number of observed difficulties (video ratings of increased effort, instability, wheel or tip slippage, or wheel or tip entrapment) on detectable warning surfaces. Lowest score = most difficulties observed.

*** Preference score computed as follows:

# of times participants included surface in 3 best
+ # of times participants mentioned surface as the best
– # of times participants mentioned surfaces as the worst

Highest total score = surface which objective and subjective measures indicate caused least difficulty relative to brushed concrete.

Objective data are the numbers of observed difficulties by aid and by detectable warning surface, taken from Table 4 (in which the types of difficulties, by aid, can be seen). The highest score (-12) for the Subtotal-Objective indicates that surface F was observed to have the fewest difficulties. The lowest scores (-40) indicate that surfaces B and D were observed to have the greatest number of difficulties.

Subjective data are preference scores computed from participants' choices of surfaces, with regard to both negotiability and safety, as among "the best", "the three best", and "the worst".

The highest score (+21) for the Subtotal-Subjective indicates that surfaces F and I were the most preferred surfaces, while the lowest score (-8) indicates that surface O was least preferred.

Table 9 presents the detectable warning surfaces in rank order, based on the algebraic sums of objective and subjective scores presented in Table 8.

Table 9.

Rank Order of 9 Detectable Warning Surfaces Tested for Safety and Negotiability on Slopes.

Surface (rank ordered by total score*)	Observed difficulties**		Preference Score***		Total Score****
F	(-12)	+	(+21)	=	+9
K	(-23)	+	(+18)	=	-5
I	(-35)	+	(+21)	=	-14
A	(-21)	+	(+6)	=	-15
L	(-35)	+	(+3)	=	-32
D	(-40)	+	(+7)	=	-33
O	(-25)	+	(-8)	=	-33
M	(-31)	+	(-4)	=	-35
B	(-40)	+	(-1)	=	-41

* Letter designations for surfaces are the same as for tests of detectability.

** Negative values of these scores are number of observed difficulties (video ratings) on detectable warning surfaces. Lowest score = most difficulties observed.

*** Preference score computed as follows:
# of times participants included surface in 3 best
\+ # of times participants mentioned surface as the best
– # of times participants mentioned surfaces as the worst
Highest total score = surface which objective and subjective measures indicate caused least difficulty relative to brushed concrete.

**** Observed Difficulties and the Preference Score for each surface were algebraically summed.

Specific Surface Comparisons.

Several specific comparisons of surfaces are of interest in exploring general design implications of these results.

Surface A vs. Surface B: These surfaces employ similar domes of relatively small size. The principle difference between them is the surface material itself, surface A made from rubber and surface B from a hard composite. Surface B clearly caused more problems than did surface A, mostly attributable to additional slipping and trapping of wheels, among users of "wheels" and also among the two participants in the "tips" group whose aids have wheels (i.e. rollator walkers). Surface D was the only other surface made of a hard composite. It also resulted in slipping and trapping of wheels.

Surface D vs. Surface I: Both of these surfaces employ relatively large, flat-topped domes. Surface D is a polymer composite having additional rough texture elements on top of and between the domes. Surface I is a polymer concrete, having lower, more rounded texture elements on top of the truncated domes, and no texture elements between the domes. Surface D was observed to result in significantly more difficulties for users of "wheels," particularly slipping and trapping of wheels, than Surface I.

Surfaces D and I vs. Surfaces A, F, and K. The difference between these two groups is that surfaces D and I have larger domes. Objective data showed that surfaces A, F, and K caused significantly fewer problems for one or both groups of aid users.

Surface O vs. Surface M. These two surfaces are both stamped metal with an abrasive coating; their design specifications are nearly identical. It is of interest to determine whether performance and subjective evaluations indicated any difference between the two surfaces. Objective data indicate no significant differences (although among wheels users there is an apparent difference in scores). Subjective ratings and preferences indicate that these surfaces were perceived as very similar.

Surface F vs. all other surfaces. Surface F differed from all other surfaces in three respects. First, it was the only surface included in this test which was comprised of ceramic tile. Second, the spacing between domes, circumference to circumference, was wider than any other surface tested--and, indeed, the center-to-center spacing was greater than specified in ADAAG 4.29.4. And third, Surface F was the only surface tested in which the domes were aligned horizontally and vertically vs. diagonally. (n.b. This horizontal/vertical alignment does fall within the ADAAG specification, although it differs from the figure shown in "Detectable Warning Bulletin #1" available on request from the Architectural and Transportation Barriers Compliance Board.)

Surface F appeared to be better than all other surfaces on most objective and subjective measures. However, because it differed from all other surfaces in three different ways, it is not possible to say whether this superiority was attributable to the surface material (ceramic tile), to the wide inter-dome spacing, or to the horizontal/vertical alignment of the truncated domes. It seems clear, however, that none of these three characteristics contributes importantly to difficulty or lack of safety in negotiation. Indeed, while persons with physical disabilities had previously anticipated that wheels would become trapped, and negotiation thus more difficult as well as somewhat less safe, on surfaces having domes aligned horizontally and vertically, this does not seem to be the case.

Furthermore, the wide spacing, as well as the horizontal/vertical alignment of the domes on this surface enabled users of "wheels" to deliberately place one or more wheels between the domes. This appeared to reduce the effort required for persons using "wheels" to negotiate this surface. Similar effects were observed for persons using "tips."

In summary, these comparisons indicate several design considerations that may be non-intuitive. The comparison of surfaces D and I with surfaces A, F, and K indicates that larger domes are not necessarily safer nor more negotiable; and the comparison of surfaces A and B indicates that surface material itself may be an important factor, and that a hard composite may induce more slipping and trapping than a resilient rubber surface.

Professional summary

Report of Linda Desmarais, Registered Physical Therapist.

[Linda Desmarais, R.P.T., had significant input to the design of the video rating scales. She also was one of the three video raters. She was asked to report from a clinical perspective on the observed travel difficulties associated with warning surfaces, especially with regard to safety, and also with regard to participant population characteristics, particularly degree of mobility.]

Descriptions of observable performance.

1. By aid.

"No aid": Not surprisingly, disabled participants requiring no aid performed consistently well on all surfaces. Even those with prostheses or braces showed good negotiability and few threats to safety. Although some of these participants presented with diminished sensation in their legs, their skill at moving about on uneven terrain or bumpy surfaces appeared to be sufficient to allow them safe travel on these surfaces. Unlike those who rely on the small area of a crutch or cane tip, or the moving area of a wheel on a walker, these participants have only to contend with extensions of their own bodies, in prostheses or shoe braces or such. The diminished sensation apparent in some participants' legs did not generally appear to affect the safety or negotiability of travel on detectable warnings.

"Wheels": Clearly, many of the participants using power and manual wheelchairs and three- and four-wheeled scooters are excellent candidates for using their equipment in general public areas; some, however, are not. Power wheelchair users demonstrated few, if any, difficulties on any surfaces, relative to brushed concrete. Those who were proficient in using their manual chairs usually demonstrated strength and confidence on all surfaces. One person, who used a standard manual wheelchair and had multiple sclerosis, demonstrated consistent difficulty on many surfaces. This participant is typically transported in his wheelchair by an assistant when he is traveling outdoors.

Users of wheelchairs with small and narrow front wheels exhibited more difficulty than those who had standard front wheels. On several surfaces, these smaller wheels appeared to get caught in the space between domes. Similarly, weight distribution appeared to be a problem in one case, where the participant was paraplegic and his legs were rather atrophied. Hence, his center of gravity was placed slightly more to the rear than other wheelchair users. His front wheels demonstrated a wobbliness which may have been attributable to the lack of substantial weight over them.

Performance of wheelchair users also appeared to be affected by fatigue, and it was difficult to judge whether it was truly the specific surface that presented challenges or the surface's placement in the testing order. Retesting on brushed concrete, halfway through the trials, helped the raters determine whether an effect was due to fatigue or to specific surfaces, but this judgment was always difficult, as reflected in the variability across raters [results - B.L.B.].

Clearly some surfaces early in their trials appeared to present more difficulties than others later in the trial, leading us to conclude that some surfaces were truly better and others worse for safety and negotiability.

"Tips": In general, those participants using canes, crutches, or walkers present with the most threats to stability among the three groups of participants. As the aid is a totally separate piece of equipment from the body, it is at risk for slipping, making uneven contact with the ground (and hence, giving the participant inconsistent feedback, thus producing more instability), or becoming trapped in the domes. In any of these cases, the participant relies on the consistent contact of the aid with the ground in order to proceed safely. If this is denied, their sense of security, stability, and safety is threatened. These conditions make canes, crutches and walkers the most risky of assistive equipment, generally, and it is not surprising that participants using "tips" were observed to have the most difficulties on detectable warnings.

The size of cane/crutch tips or walker wheels also appears to relate to safety and negotiability. The smaller the tips or wheels, the greater the tendency for difficulties with safety and negotiability. The smaller tips and wheels appear to get caught between the domes or lay on an angle between the base and the dome, thus causing the participant to appear less stable. Wheeled walkers performed similarly to wheelchairs, creating a bumpy and less safe trip on those surfaces which had more closely spaced domes. Those participants with four-wheel walkers had great difficulty negotiating, and exhibited safety concerns, most likely from their lack of solid traction or stopping ability with the four wheels. As with some of the users of wheelchairs (above), persons with wheeled walkers of any kind would be less likely to traverse in public areas or to use public transit. They would be more likely to use paratransit for shopping trips and other such public excursions. Those cane users who are more apt to go out in public would -- and should -- be using large cane tips. Those participants tested with crutches performed more like those with no aids than like those with canes or walkers; participants using crutches appeared safer and generally negotiated all warning surfaces better than other members of the group using tips.

2. Disability-specific observations.

Spasticity: A number of participants presented with disabilities that are a consequence of central nervous system impairments, such as cerebral palsy, paraparesis, or hemiparesis. Many of these participants presented with spasticity, which under normal mobility conditions was controlled by a brace or resting position in a wheelchair. Negotiating on a bumpy surface elicited an increase in spasticity for two participants, evidenced as clonus responses, but in no case did the increased spasticity cause observable safety or negotiability difficulties.

Fatigue: Some neuromuscular conditions, such as multiple sclerosis, manifested difficulties through the presentation of fatigue and compensatory patterns of movement. For some of these participants, negotiating on a brushed concrete surface was quite difficult; maneuvering up and down a bumpy surface with varying amounts of traction appeared to be exhausting. In addition to being a bar to negotiability, fatigue represents a potential safety risk because persons with such fatiguing conditions are likely to be limited in their ability to stop quickly. As mentioned above, because such participants are vulnerable to fatigue, it was difficult to ascertain whether it was a particular surface that was more challenging than the others, or whether it was its placement in the order of trials. Again, such persons are also less likely to be active, independent travelers in the community.

Over-anticipation: Some participants presented with disabilities that manifested themselves with a shuffling gait. These participants are more inclined to require the assistance of an aid such as a cane, crutch or walker. Because of their disability, such persons frequently resort to over-anticipation of ground-level obstacles. They may take smaller steps or shuffle their feet more as they anticipate an uneven or bumpy surface, as a means of protecting themselves from a potential threat to stability. This common tendency was observed in participants' negotiation of the various surfaces, making it difficult to assess through observation alone whether a change in gait indicated that a particular surface in fact posed a threat to stability, or rather reflected only an anticipated threat based on visual appearance.

Discussion.

Generally speaking, persons with disabling conditions that do not require an aid, but might include a brace or prosthesis, exhibited few if any difficulties in safety and negotiability on slopes with detectable warning surfaces. Persons using power wheelchairs or scooters, likewise exhibited little difficulty. On the other hand, some persons with disabling conditions requiring manual wheelchair use or assistance of cane or walker did exhibit difficulty on these slopes.

Of the seven participants identified in the quantitative analysis as having numerous difficulties, four were users of wheelchairs, two used rollator walkers and one was equipped with leg braces and a quad cane. Note that all four users of wheelchairs were users of manual chairs; not surprisingly, most or all were rated as exerting additional effort on up ramps, across all surfaces (except surface F). One of the four (discussed above), has a displaced center of gravity that apparently puts him at risk for slipping and entrapment of his extremely small front wheels. Another one of the four, with multiple sclerosis, has limited upper body strength and was at high risk for fatigue; she had negotiability difficulties only on up ramps. Importantly, three of the four are strong, active travelers and are unlikely to be significantly impeded or placed at risk by any of the warning surfaces. They appeared to compensate well for the various difficulties observed.

The three participants in the "tips" group with numerous travel difficulties present a different issue. None are active travelers; in fact, rollator walkers and quad canes are typically used in the home, not as wide-ranging mobility aids. The two persons using rollator walkers encountered wheel entrapment across many or all of the surfaces. All three individuals were at risk for stability across many or all of the surfaces, as they are in general. Thus, unlike the four users of wheelchairs discussed above, these three participants are unlikely to be candidates for independent travel in public areas.

Finally, it is important to consider safety issues related to those participants who exhibited only few travel difficulties. One cannot assume that the infrequency of difficulties insures that those difficulties do not pose a safety risk to those individuals. Observation shows, however, that in no case were participants at grave safety risk on any of the surfaces. In fact, nearly all showed the ability to compensate well for the travel difficulties imposed by the warning surfaces.

SUMMARY AND CONCLUSIONS

There are two major issues which can be addressed in the findings of the tests of safety and negotiability of detectable warnings on slopes, for persons having physical impairments.

- Are there major safety concerns?
- Are there differences between surfaces or surface characteristics which result in differences in safety and negotiability?

Before presenting conclusions regarding these two issues, the reader is reminded that although the tests of safety and negotiability in this project were quite stringent in some respects such as the steepness of slope, the amount of warning material to be traversed, and the deliberate inclusion in the sample of those persons who were considered most likely to experience difficulties as a result of detectable warnings, nonetheless, all were all completed under dry conditions.

With regard to safety, of 40 participants, none were considered by the consultant physical therapist to be at serious risk as a result of the addition of detectable warning surfaces to slopes. Four participants exhibited serious difficulty negotiating these surfaces, but their difficulties were indicative of general mobility limitations, and not necessarily related to the surfaces themselves. These were individuals who would probably be very limited in the extent of their independent travel--at least using the aids with which they completed this testing. Three of these four used rollator walkers or quad canes for the testing, but would probably use a wheelchair for extended travel because it offers greater security. An additional three participants, who used manual wheelchairs, and who were severely impaired, showed substantial difficulty in negotiating the warning surfaces, but they did not appear to be at risk. These three were very active travelers despite the severity of their disabilities and the difficulties they encounter as a result of any bumpy surface. The remaining 33 participants appeared to compensate quite well for difficulties they experienced as a result of the detectable warnings.

With regard to differences between surfaces, or characteristics of surfaces, there are important trends, although the variability of both objective and subjective measures as a result of individual differences in travel aid and disability make it difficult unambiguously to conclude that particular surfaces are outstandingly better or worse than others, with regard to ease of negotiability and safety.

The strongest finding was that surface F appeared to create the least difficulties for any group, and particularly for the group using "wheels." The superiority of surface F was further confirmed by subjective data from both the "wheels" and the "tips" users. It is not clear what made this surface better, however, as it was the only surface having the following characteristics: horizontal/vertical alignment of truncated domes; the widest inter-dome spacing combined with relatively small domes, thus exposing more of the base level of the surface than was exposed on other surfaces; and it was unglazed ceramic tile.

An additional observation with regard to surface F is important. Namely that concern has been expressed by persons with physical disabilities and their advocates that a surface with horizontal/vertical alignment would be more likely to result in wheel entrapment, and consequent loss of control for wheelchairs than surfaces having diagonal alignment. This definitely does not seem to be the case. Persons with visual impairments have also expressed the opinion that domes aligned diagonally are easier to detect than domes aligned horizontally/vertically. This also does not seem to be the case, as detectability of surface F has been demonstrated to be statistically equal to detectability of surfaces having diagonal alignment (Bentzen et al. 1994).

More generally, surfaces A, F and K seemed to promote few difficulties and to be well liked. The common characteristic of these three surfaces is relatively small domes.

Surfaces which caused the most difficulties differed somewhat across groups. Among users of "wheels," surfaces B and D were troublesome, as reflected by both objective and subjective measures. Among users of "tips," surfaces B and I were observed to cause the most difficulties, but, clearly, many "tips" users rated I highly.

Both "tips" users and participants who used "no aid" were in agreement with a subjective dislike of surfaces O and M, possibly because of perceived slipperiness. This was not confirmed by especially poor performance by these groups on these surfaces, however.

It should be noted that the fact that a surface is perceived as difficult or unsafe, while it may not accurately reflect performance on such a surface, is nonetheless important. All persons tend to dislike or avoid surfaces which they perceive to be hazardous; this is no less true for persons with physical disabilities. It is important that detectable warnings surfaces not be used which persons with physical disabilities would wish to avoid--making some otherwise accessible routes inaccessible to certain individuals.

Resilient surfaces may provide better slip resistance than comparable non-resilient surfaces, as can be seen in comparing data for slipping on surfaces A and B.

Larger domes do not appear to result in fewer difficulties than smaller domes, as can be seen in comparing the relatively good performance of surfaces A, F and K versus surfaces D and I.

RECOMMENDATIONS

Given even the moderately increased level of difficulty and decrease in safety which detectable warnings on slopes pose for persons with physical disabilities, it is desirable to limit the width of detectable warnings to no more than that required to provide effective warning for persons with visual impairments.

Appendix A

Steering Committee

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Appendix B

Ramp____________ Participant #_________

Subjects in any kind of wheelchair or scooter

-1	0
I---------------------	-I
worse	same

Relative to Performance on brushed concrete

Going up:

______ 1. **Effort required to start from stop.**
e.g., in a manual chair subject may lean forward more by placing center of gravity forward or show difficulty of transitional movement of wheels

______ 2. **Stability.**

______ 3. **Wheels slip.**
Look for discontinuity in wheel motion, particularly when going up, incongruent with activation of the chair or scooter. Also look for overshooting as a result of slipping when attempting to stop—particularly when going down.

______ 4. **Wheel(s) becomes trapped in domes.**
Look for difficulty turning, if wheels are between domes. Also look for exaggerated oscillation of front wheels.

Going down:

______ 1. **Stability.**

______ 2. **Wheels slip.** (see above)

______ 3. **Wheel(s) become trapped in domes.** (see above)

Rater's comments In this section you should note anything you think wasn't appropriately covered by the scale, that is surface related, i.e., ease and safety of travel over the surface, not individual subject variation in performance such as fatigue or change in foot or body placement in normal anticipation of stopping. Some things to look for in a general sense are subjects' accuracy of stopping, continuance of wheelchair motion during transitional hand lifts and how they relate to safety and ease of travel over the particular surface. **Remember these comments will assist us in our critical discussion of the difficulty or threat to safety that these surfaces present to various handicapping conditions.**

Ramp____________ Participant #_________

Subjects using any kind of cane, crutches, or walker

```
-1                 0
I------------------I

worse            same
```

Relative to Performance on brushed concrete

Going up:

______ 1 **Effort required to start from stop.**
Evident in body or foot placement.

______ 2. **Stability.**
Evident by change in gait pattern, or body movement indicating that the subject feels less stable on this surface relative to the concrete surface.

______ 3. **Aid slips.**
May be due to decreased slip resistance of warning surface.

______ 4. **Aid becomes trapped in domes.**
Grooves between domes or shape of dome may interfere with ease of travel or subject's normal gait pattern.

Going down:

______ 1. **Stability.** (See above)

______ 2. **Aid slips.** (See above)

______ 3. **Aid becomes trapped in domes.** (See above)

Rater's Comments In this section you should note anything you think wasn't appropriately covered by the scale that is surface related, i.e., ease and safety of travel over the surface, not individual subject variation in performance such as fatigue or change in foot or body placement in normal anticipation of stopping. Some things to look for and keep in mind might be adjustment/change in aid/feet (gait) when starting to go up from a level, i.e., the very first step (please note, if possible, whether it is the feet or the aid that changes), length of time aid is in contact with the surface- dragging of the aid etc., accuracy of stop (if less, note if undershot or overshot). Most of these will be very obvious and extreme in nature if they are present at all. **Remember these comments will assist us in our critical discussion of the difficulty or threat to safety that these surfaces present to various handicapping conditions.**

Ramp____________ Participant #_________

Subjects who walk without an aid

-1 0
I--------------------I

worse same

Relative to performance on brushed concrete

Going up:

_____ **1. Effort required to start from stop.**

_____ **2. Stability.**
Evident by change in gait pattern, or body movement indicating that the subject feels less stable on this surface than on the concrete surface.

Going down:

_____ **1. Stability.**

Rater's Comments In this section you should note anything you think wasn't appropriately covered by the scale, that is surface related, i.e., ease and safety of travel over the surface, not individual subject variation in performance, such as fatigue or change in foot or body placement in normal anticipation of stopping. Some things to look for and keep in mind might be any adjustment/change in gait when starting to go up from level, i.e., the very first step. For example, you might note whether the bumpy surface effects balance, making it easier or harder to go up/down the surface, or whether foot or body placement on the bumpy surface indicates relative ease of travel or safety compared to the concrete surface. You would also want to note if a participant has a wider gait, wobbly ankle or any exaggerated changes in the placement of feet, on the warning surface. **Remember these comments will assist us in our critical discussion of the difficulty or threat to safety that these surfaces present to various handicapping conditions.**