

An Innovative Design Program for Engineering Students

Bruce Ankenman, Stacy Benjamin, and Philip Jacob

The Segal Design Institute in the McCormick School of Engineering at Northwestern University offers an innovative design course called Engineering Design and Communication (EDC). EDC is a required program for all engineering undergraduates and is generally taken in their freshman year. EDC is team-taught by faculty from both engineering and writing disciplines. EDC uses real projects for real clients to teach students how to (1) design effectively in response to real-world problems and (2) communicate effectively as part of the design process.

EDC teaches a user-centered approach to design. It emphasizes that the most technically elegant design solutions are destined to fail if they do not address real user and stakeholder needs. Moreover, needs cannot always be understood by simply asking questions. It is also necessary to ob-

serve users in actual settings and to test prototypes with real users.

EDC projects come from a variety of domains and are submitted by actual clients, including corporations, not-for-profit agencies, entrepreneurs, and individuals. These projects require students to use various engineering tools and techniques to define the problem, generate alternatives, observe and interview users, build mock-ups, conduct design reviews, and produce models or prototypes. Projects culminate in a prototype, written report, and oral presentation.

Students have participated in designing solutions for a number of problems commonly encountered by people with a disability. The following three articles demonstrate this process and the design solutions developed by the students to assist stroke survivors in performing everyday tasks.

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The Knee Nook

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Although the effects of a stroke vary, survivors often have limited use of one side of their body. Stroke survivors may wear an ankle-foot orthosis (AFO) to prevent their weak foot from dragging and hindering ambulation. Because of the added bulk of an AFO, donning a shoe becomes difficult. The design team, composed of freshman engineering students in the Engineering Design and Communication course at Northwestern University, interviewed stroke survivors to understand the problem and then constructed several prototypes as possible solutions. After stroke survivors tested and critiqued each prototype, the Knee Nook emerged as the most promising. Stroke survivors often place their weak foot on top of their strong knee, similar to the position of crossing one's legs, to allow them to easily reach their foot. Keeping the weak leg in place on the strong thigh while donning the AFO is often difficult. The Knee Nook is a hands-free device that holds the user's leg in this position. The device is placed on top of the user's strong knee and employs a neoprene pad to easily hold the weak leg over the strong knee. This design allows stroke survivors to independently don an AFO and shoe. **Key words:** *AFO, design, stroke*

After surviving a stroke, people often experience a loss of muscle control. The muscle weakness often occurs in the arm and leg of one side of the body, which results in either hemiplegia or hemiparesis. Stroke survivors often experience foot drop because they cannot raise the ball of their foot off the ground. Furthermore, the knee may be weakened, possibly resulting in the knee buckling while walking. Another stroke side effect is abnormal muscle tone—either flaccidity (decreased muscle tone) or spasticity (increased tone). To alleviate the problem of foot drop, an ankle-foot orthosis (AFO) is usually prescribed to prevent the weak foot from dragging and hindering ambulation. There are different variations of AFOs, including hinged or unhinged and cut or uncut. Because of the added bulk of an AFO, donning a shoe becomes difficult. The task is further complicated by the fact that the user may only have the use of one hand. Other problems stroke survivors face in donning their shoes include difficulty in lifting the leg, bending the knee, bending the ankle, maintaining balance while putting on a shoe, keeping the shoe stationary, and pointing the toes. In addition, because the AFO is constructed of rigid plastic, it often ends up crushing the back of the shoe when the user applies force.

Although commercial products do exist to help stroke survivors don their shoe while wearing an AFO, they are only marginally effective and depend

heavily on the user's skill and preferred technique of donning his or her shoe. For example, the heel cup from one manufacturer holds the shoe open to allow the user to more easily place his or her foot in the shoe. However, it is too bulky and very difficult to remove when the foot has been fully inserted. Extra-long shoe horns, another commonly used aid, are often difficult to maneuver given the user's limited use of one side of the body.

The goal in designing the Knee Nook was to create an easy to use, highly effective, portable device that allows stroke survivors to easily and independently don their AFO and shoe. It was important to create a device that was hands-free once set up, given that the user had to perform all tasks with a single hand.

This article describes the process used to develop the Knee Nook, and the importance of integrating the comments and observations of stroke survivors at each step along the way.

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User Interviews

The design team interviewed stroke survivors at the Rehabilitation Institute of Chicago. They were able to observe the stroke survivors during the process of putting on the AFO and shoe. One user preferred a method that involved crossing the weak leg over the strong knee to more easily reach the foot. However, the user struggled to keep the leg crossed and eventually had to take a break because of the extreme exertion. Another user preferred placing the AFO–shoe combination on the ground and using the strong arm to lift the foot and slide it in. This method was obviously very difficult; even though the user persevered, it was obvious that this method was physically taxing.

These interviews and observations allowed the team to learn firsthand about the problems associated with donning AFOs and shoes. These observations were used to design four very different mock-ups: a lever-assisted shoe horn, an adjustable wedge base, a tongue clip, and the Knee Nook.

Design Concepts

Lever shoe horn

Rationale

Both users had trouble putting their foot into the shoe without crushing the heel. To compensate for this problem, their podiatrists recommended custom shoe horns, but the users still had trouble pushing their foot completely into the shoe. The team proposed a new device: a shoe horn with a lever (**Figure 1**). This device allows users to slide their foot into the shoe and pull a lever, giving their foot an extra push completely into the shoe.

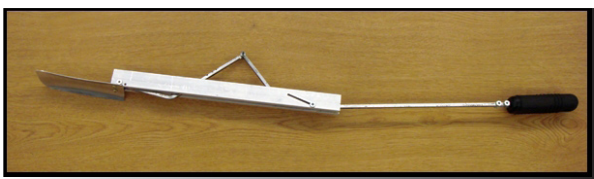


Figure 1. Lever shoe horn prototype.



Figure 2. Shoe wedge prototype.

Description

The lever shoe horn is used much like a regular shoe horn: Users simply place it in the back of their shoe to aid in sliding their foot into the shoe. Users can actuate the handle on the lever shoe horn to push the back of their foot. The device is constructed out of metal, with a rubber handle at the top for comfort.

Shoe wedge

Rationale

Because the AFO holds the foot at a 90° angle, users had trouble sliding their foot into a shoe that was parallel to the ground. Placing the shoe at an angle should allow the user to swing their foot into the shoe more easily.

Description

The design for the shoe wedge (**Figure 2**) is fairly simple. It consists of two metal pieces riveted to a hinge. The bottom is covered with Dycem® nonstick material to prevent slippage. The top is coated with a coarse material to increase friction between the shoe and the apparatus. Additionally, a Velcro strap provides more stability for the shoe. An adjustable mechanism allows the wedge to be placed at the angle most comfortable for the users.

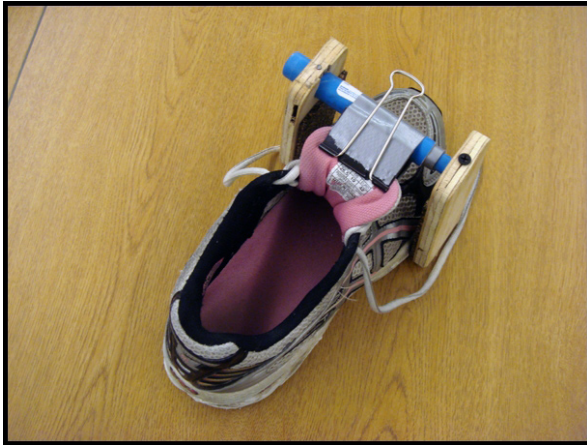


Figure 3. Tongue clip prototype.

Tongue clip

Rationale

Users were faced with a recurring problem. As they put on their shoes, the AFO would push the tongue into the bottom of their shoe. This improper donning forced them to back their AFO out of the shoe, fix the shoe's tongue, and start the whole process over again. A proposed idea to address this problem is a tongue clip, in which the tongue of the shoe is held firmly in place at the front-top of the shoe. This ensures that the tongue will not slide and provides a large opening for the users to don their shoe with ease.

Description

The tongue clip (**Figure 3**) is a spring-loaded device that fits over the top of a shoe. High friction pads prevent slippage and a clip attaches to the tongue of the shoe to hold it back.

Knee Nook

Rationale

Stroke survivors often place their weak leg on their strong knee, similar to a person crossing their legs, as a way to more easily reach their weak foot. However, they experience difficulty holding their leg in this position. The original Knee Nook holds the weak leg on top of the strong knee. The device

allows users to easily reach their foot and thus more easily don their AFO and shoe.

Description

The original Knee Nook consists of three main parts: the body, the leg strap, and the pivoting support. Users strap the device on top of their strong knee, leaving the pivoting support hanging down. Users then swing their weak leg over the device, causing the pivoting support to rotate and lock into position when the leg is perched atop the strong knee. The prototype device was constructed out of wood and used Velcro for attachment straps. For added comfort and safety, a foam pad was attached below the body of the device to ensure that the user's knee was not subjected to great amounts of pressure.

User testing

Users tested each of the prototypes for function and ease of use. In deciding on the final design direction, the team considered which device provided the most functionality. First, two disadvantages were observed in the lever shoe horn. There was no adequate way for the user to hold the device. The client also did not see hope in the approach as a whole, because the device limits critical space behind the shoe.

The wedge and the tongue clip both marginally assisted the shoe donning process. However, neither design allowed the users to fully don their shoe. Also, the client pointed out that most users prefer to put on their shoe with their weak leg resting on their strong knee. These users would have no use for the wedge.

The Knee Nook was the only mock-up that assisted the user in fully donning both the AFO and shoe, which therefore made it the clear choice for the team's final design direction. For the device to be successful, however, many changes needed to be incorporated. Having a support underneath the leg and a second strap reduced the device's usability. The size and mechanics of the device were cumbersome and confusing to the user. However, the device's ability to hold the user's weak leg atop the strong leg was ideal. The team's original idea was to construct a smaller, collapsible version of



Figure 4. How to use the Knee Nook.

the Knee Nook. However, after an intensive design review, it was obvious that the Knee Nook needed to be completely redesigned.

The new design would be ambidextrous, have no mechanisms, be easily adjustable, have no hard surfaces, slide onto the leg, and be highly portable. A nonslip ring was suggested as another way to hold the leg atop the knee. The team modified this idea to make it adjustable for different leg sizes by proposing a nonslip pad affixed with a strap. Of many attachment methods considered, backpack straps were found to be the most intuitive and familiar to the users. Because it was determined from user testing that only one strap was necessary, 1-in. webbing was used in conjunction with backpack-like attachment clips. A stuffed neoprene pad provides the friction necessary to hold the leg in place, which, like the original design, does not require the users to lift their leg overly high.

Thus, after deciding on the Knee Nook as the final design direction, the team redesigned the original mock-up. The proposed design retains all the advantages of the original, while transforming the overly complicated and bulky design into one that is elegantly simple.

Final Design and Direction

The Knee Nook allows stroke survivors with limited use of one side of their body to more easily don an AFO and shoe. Stroke survivors often place their weak foot on top of their strong knee, similar to the position of crossing one's legs, to allow them to easily reach their foot. To hold the users' leg in this position, the team designed the Knee Nook. The Knee Nook is a hands-free device that holds

the users' leg in this position, which they often have trouble maintaining on their own. The device is placed on top of the users' strong knee and employs a neoprene pad to easily hold the weak leg over the strong knee.

Using the Knee Nook is very simple (**Figure 4**). While sitting in a chair, the users slide the device over their strong leg into position above their knee, strapping the device using the tightening mechanism. Once secured, the users lift their weak leg onto their strong knee. The Knee Nook then holds the users' foot in a position ideal for donning a shoe.

The Knee Nook has two main parts: the neoprene pad and the straps. The device is fastened atop the strong knee using a strap that employs simple pulling clips for easy one-handed adjustment. The neoprene pad serves as a means to keep the foot on top of the leg. This allows the user to more easily reach their weak foot and also restricts the foot's motion, giving the user more control while donning their AFO and shoe. Specific features are detailed below.

Leg strap

One durable leg strap made of 1-in. webbing tightens with the same technology used in backpacks for years (**Figure 5**). The product starts with 36-in. of durable, easily washable strap allowing each user to determine what size works best for them and then cut off any excess. After a one-time adjustment, there is no need to disconnect the straps; they easily slide up the leg and can be tightened and loosened with an easy upward pull once in place. The reversibility of the device al-



Figure 5. Leg straps and neoprene padding.

lows users to choose which side of their leg they wish to tighten the straps on, leading to easy accessibility for users with either left- or right-side hemiparesis.

Neoprene padding

The neoprene padding, keeping the leg in place and serving as a shock absorber, is much easier to clean than many regular types of foam. It also provides a great amount of comfort. The padding will not stick to clothing or leave behind any residue, so users can be confident using it with even their nicest clothes. The thickness and design of the foam also allow it to be sewn, not glued, into place contributing to the Knee Nook's overall durability. The Knee Nook is designed to be aestheti-

cally pleasing and easily portable. The device is constructed with economy in mind, and all parts are designed to function with minimal adjustment from the user. Therefore, the Knee Nook is designed to be highly functional, while its ease of use and transport allows for seamless integration into the users' lifestyle.

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Design of a Cafeteria Tray for Use by Stroke Survivors

Yemi Adetiba, Ben Kolodner, Kathy Kubacki, and Andrew Park

Survivors of a stroke present varying types and degrees of neurological impairments and functional deficits. They often have difficulty using one side of their body and may require assistive devices such as canes and walkers. As a result, carrying a standard cafeteria tray can pose a challenge to these individuals. Our goal was to design a cafeteria tray that could be easily used with one hand. User interviews of stroke survivors offered client needs that guided the entire design process. It was important to the stroke survivors that the device required intuitive understanding of use, effectively transported food using only one hand, supported the weight of a meal, and had a pleasing design to promote discreteness by avoiding a “disabled” appearance. **Key words:** *adaptive device, design, stroke*

Survivors of a stroke present varying types and degrees of neurological impairments and functional deficits. For example, more than 50% of stroke survivors demonstrate a persistent walking deficit, which not only limits these people’s functional independence but also decreases their confidence to perform normal daily activities within the home and community. Recovery of arm function is generally worse. Many stroke survivors have limited or no use of one arm. As a result, carrying a standard cafeteria tray poses a challenge. Currently, the only available alternative is a tray with a handle positioned above it, similar to a basket. However, in some cases, stroke survivors require the use of a cane or walker, which would make this device difficult to use and cause it to act as an hinderance rather than an aid. In addition, the basket would not provide a sufficient amount of stability for the users. The tray design must be strong enough to support the weight of the user and sturdy enough to keep the tray in place. For stroke survivors who have undergone successful rehabilitative therapy, the basket appears to be a plausible solution; however, the strength of stroke survivors varies and a solution should exist that can address users with every level of impairment.

User Interviews

We interviewed stroke survivors at the Rehabilitation Institute of Chicago who had limited or no

use of one arm. From these interviews we determined several user preferences.

User preferences

Social use

Stroke survivors expressed an interest in a design functional in all situations, even for people who did not have a stroke and were only temporarily unable to use one arm, for example, due to carrying a baby.

Types of devices

Stroke survivors had a strong dislike of any device that would be directly attached to the body. They also expressed an interest in the ability to put external items such as a cane, wallet, or purse in the device while they were getting food.

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Discreteness

Users did not want to stand out in a crowd and therefore expressed interest in a design that would not look “disabled.” The device would be intended for the use of the stroke survivors but should be able to encompass a broader range of individuals, even those who have full motor capacity on both sides of their bodies.

Existing products

The only existing product found that attempted to solve this problem was a high friction surface tray with handle. This was not a well-designed product for stroke survivors, our primary user group.

Implications for alternatives

After completing the user interviews, we determined that the following must be considered while producing mock-ups and prototypes:

- *Independence.* Stroke survivors want to become as independent as possible. Therefore, it is important to construct a device that can be used without any assistance from other individuals. Its mapping should be clear, and its use should be well defined.
- *Appearance.* A device must be designed that would blend into a normal situation such as a mall or a cafeteria.
- *Support.* The device should be able to hold a large amount of weight, because some stroke survivors use canes or walkers to walk; it should temporarily be able to fulfill the job of the walker or cane.

Design Concepts

Alternative concepts

After brainstorming ideas to address user needs, we implemented the best ideas in two alternative concepts. The alternatives were intended to answer the following questions:

- Is the device functional with the use of one hand?
- Does the device transport food throughout the cafeteria?

- Can it reach over the ledges?
- Is the device stable?
- Are specific instructions required to understand and use the device?

User testing was conducted at the Rehabilitation Institute of Chicago to determine which of the alternatives was preferred. Based on the stroke survivor’s ratings of the devices after completion of several tasks including placing a tray onto the device, maneuvering through the cafeteria, and finally attempting to pick up food, the best solution was chosen. The evaluation criteria was a scale of 1 to 10 to provide quantitative data, although the users also were asked to provide any feedback, whether positive or negative, regarding each design.

The two designs that we developed were a walker tray with an attached tray on drawer slides and a shopping cart tray that could be pushed over the ledges of the cafeteria.

Walker tray

The walker tray is based on the idea of a walker that some people utilize for additional stability after experiencing a stroke. The amount of stability provided by such a device was the most persuasive factor leading in the creation of this design. To incorporate a tray, a flat surface was constructed atop the legs that could slide over the ledge; this was accomplished through the use of drawer slides (**Figure 1**).

The walker needs to be pushed with two hands; however one hand is sufficient to move the tray while the other hand is used to steer. This mock-up was constructed to test where users would prefer the stability to be concentrated—toward the center of their bodies or to the sides, as in the walker. The walker provides additional stability to the tray, because it lies atop long bars under its width. Although the design of this walker would limit the movement of the primary users by surrounding them on three sides, it would offer the most support along its surface area.

Shopping cart tray

The shopping cart alternative is based on a grocery store shopping cart (**Figure 2**). Because



Figure 1. The walker tray design demonstrating the tray in the slid out position.



Figure 2. The shopping cart alternative.

grocery shopping resembles the action of getting food in the cafeteria, the shopping cart was used as a model product for the design. The device was constructed in such a way that a tray would be placed atop the ledge of the cart, which would then be slid over the cafeteria ledge. Meanwhile, there would be enough space between the tray and the ledge for the cart to slide side-to-side along the ledges of the cafeteria. This design also eliminated the enclosure users faced in the walker tray.

In both alternatives, wheels provide the users with easy maneuverability. However, a major difference between the two designs can be found in the location of the handle. The centered handle would cause the user to exert forces forward and downward if they experienced a loss of balance. As a result, the cart would have to be designed in such a way to prevent it from tilting backward when extra force is applied to it. A benefit of the centered handle is that the cart can be steered with one hand indefinitely; although the second hand can provide extra precision in steering, it is not necessary for the cart to function as intended.

Next Steps

The team decided to pursue the shopping cart alternative, because of the results obtained during user testing. Out of a possible 40, the shopping cart received 33 points, while the walker tray alternative received only 16 points.

User testing revealed several problems with the shopping cart design. Although the wheels appeared to be a benefit, users worried whether the friction levels would be so small that the cart would roll away on tiled floors. Furthermore, the removal of the cafeteria tray from the cart was another user concern. Angling the sides of the cart's tray so that the standard cafeteria tray could easily slide off was a possible solution to this problem.

Another concern was the need for cup holders. The users were asked to decide what type and how many were necessary. It was determined that one universal cup holder was the best solution. However some members of the design team believed that having two was a good idea, because some individuals prefer to have two beverages during meals as opposed to only one. As a result, a place for the cup holders needed to be found and the design needed to be determined in hopes of not compromising the idea of creating compactable carts.

The design of the shopping cart was modified and alterations were made to improve the design by adding details suggested by the users. The shopping cart alternative was explored further, because its universality was much more apparent due to its familiar design that was aesthetically pleasing and did not resemble anything "disabled." Although



Figure 3. The Caf-Cart.

the initial mock-up was constructed from wood, the final idea of creating it out of metal was unanimous. After establishing the specifications and design components that were most important to the users and would still remedy the problem, the next generation of the shopping cart was designed to be pleasing aesthetically while being practical and easy to use.

Caf-Cart

The final design, named the Caf-Cart, was composed of an aluminum metal frame and acrylic tray and cup holders (**Figure 3**). These materials, which enhance the practicality of the design and meet user requirements, are also stable, durable, and easy to clean. The 360° casters allow the cart to move in all directions, which is made even easier by the three-sided handle. The height of the cart is 36-in., which will allow the tray to glide over all the ledges at most cafeterias. Meanwhile, the hollow design prevents the cart from hitting under-ledge storage areas.

The design was constructed so that the cafeteria trays would be placed on top of the acrylic tray of



Figure 4. Caf-Cart holding a cafeteria tray.

the cart (**Figure 4**). When at a ledge, the cart along with the cafeteria tray could be pushed along the ledge, minimizing the difficulty and reach required to access the food or beverage desired. Meanwhile, there would be enough space between the tray and the ledge for the cart to slide along the ledge without restricting the user or being stopped by the under-ledge storage bins that hold plates and other items.

The placement of the handle is also another important feature, because it allows the device to be maneuverable with one hand. By extending the handle over three sides, the cart can be pushed from any direction and directed not only forward and backward but also sideways with ease.

The design provides stability, which is focused toward the center of the apparatus because of the handle placement. When pushed down upon, the cart does not buckle; it is capable of supporting 250 lbs. Furthermore, the bending of the legs shifts the center of mass inward toward the wheels, preventing the cart from tipping backward when the user pushes downward on it. As a result, users requiring the use of walkers or canes can rely on the Caf-Cart for necessary stability.

This design has nesting ability, so the carts can compact into each other, much like a grocery cart at a neighborhood food market. The 4:1 nesting ratio maximizes the number of carts storable in a limited space while still making the carts easy to access. Furthermore, the universality of the cart is much more apparent than a basket or standard tray. It is capable of functioning in numerous cafeterias due to its pleasant design, practicality, and ease of use.

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Development of a One-Handed Nail Clipper for Stroke Survivors

Christopher Carhart, Rafal Ciechowski, Doug Groat, and Alyson Stevans

Due to the physical effects of stroke, many stroke survivors experience difficulty clipping their nails. Much of this difficulty is due to weakness in the upper extremities, loss of dexterity, spasticity, and vision problems. Our goal was to design a device that would help stroke survivors shorten their finger nails, providing increased independence, convenience, comfort, and safety compared to their current method of cutting nails. From user interviews and observations, we developed several prototypes to solve this problem. The final design, the Step 'n Snip, consists of a finger nail clipper mounted on an inclined, rotatable metal rod. The clipper is attached to a foot pedal with a long steel bike brake cable, which the pedal then uses to actuate the clipper. The pedal is mounted on a base that is shaped such that it provides a nesting space for the clipper frame during storage; the two parts are kept together by a swiveling clip. The clipper itself is at a convenient height for users and is fitted with a nail clippings collection system. **Key words:** *adaptive device, design, nail clipper, stroke*

Our objective in designing the Step 'n Snip was to create a fingernail shortening device that efficiently and comfortably allows persons with any degree of limited arm and hand use in one side of their body to shorten their fingernails easily and independently. Most stroke survivors have near full dexterity in their strong hand, and many users have varying degrees of weakness and spasticity in their affected hand. This makes using conventional fingernail shortening methods nearly impossible for many users. Current products are neither efficient nor effective in solving this problem.

There are many current fingernail shortening devices, geared mainly toward amputees, on the market that allow stroke survivors with some control and flexibility in their affected arm to clip nails on their strong hand. However, no current devices are effective in clipping nails on both hands of users with moderate to high spasticity in their weak hand or users with limited or no flexibility on their affected side. As a whole, currently available products do not address the entire problem.

Our primary goal was to enable users of all degrees of flexibility and control in their affected side to clip their fingernails independently and efficiently in virtually any location. Our secondary goals were to make the product easily storable, portable, and relatively lightweight.

User Interviews

We interviewed several stroke survivors at the Rehabilitation Institute of Chicago to determine the problems associated with clipping fingernails and features that they wanted to see in the device. The following are preferences that the users wanted to see in the nail clipper.

- *Mobility.* Users did not want the nail cutter to be stationary; they wanted to be able to easily store it in a drawer or closet. They also did not want the product to be too bulky.
- *Efficiency.* Users wanted a product that could cut nails quickly and easily.
- *Nail collection.* Users wanted a product that could collect the nail clippings.
- *Safety.* Users wanted a safe product that they would not be likely to injure themselves with.

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- *Discreetness.* Users did not want the product to obviously identify the user as having a disability. They wanted the device to look aesthetically pleasing, although this was less of a priority than the functionality of the design.
- *Ease of operation.* Users preferred an alternative improved actuation method, such as the foot.
- *Stability.* Users wanted a device that did not have the risk of sliding on the table or counter while in use.

Competitive Products

We researched competitive products to see what was already available on the market. From this we could see whether existing designs might be modified to address the new needs or how much they could be adapted or incorporated into our design. We found two devices already on the market.

Stapler one-handed device

This design consisted of a toenail-sized nail clipper mounted on a small plastic base with rubber grips on the corners of the bottom side of the base. This allowed the user to position one hand to be clipped and to press down with the free hand. Most devices of this type are designed for amputees and do not address problems of weakness, spasticity, and lack of fine motor skills that are often found in stroke survivors.

Nail clippers/nippers

Nail clippers and nippers can be used to a limited extent on the strong hand, due to the limited control in the weak hand.

Design Concepts

Implication for alternatives

All of the information we gathered from the user observations and product research gave us direction in our design process. The following are the most important aspects that needed to be included in the design:

- *Method of actuation.* The users expressed willingness to explore alternative methods of

actuation, different from what their current devices employed.

- *Stabilization.* The issue of stabilization had two parts, one dealing with stabilization of the hand, and the other concerning keeping the device itself stationary during clipping. This required a way to counteract the spasticity of the hand and to incorporate an effective nonslip grip respectively.
- *Independence.* Both the user observations stressed that the device should be used without any outside help.
- *Portability and storability.* From the user observations, we learned that it was important for the device to be mobile and easy to quickly set up and put away.
- *Safety.* From the user observation, we realized that fear of cutting the fingers of the weak hand is of great concern. We also learned that the users would like to get the fingernails on their affected hand more neatly clipped; however, they are unable to for fear of injury. Thus, the alternative concept had to be as safe as possible.
- *Discreetness.* From the user observations, we concluded that the users would like the product to be easily storable; the device should also look nice while not drawing extra attention.
- *Efficiency.* From the user observations, we learned that the operation of the product needed to be improved. Therefore, it was imperative to explore different methods of actuation, such as using different parts of the body, for the alternative concepts.

Testing

We conducted user testing sessions to evaluate all four alternative design concepts. The users were asked to perform tasks that allowed the team to see if the user could properly set up each design, to see if the user could use the design, and to gather feedback from the user.

These tasks also allowed us to observe how intuitive and how feasible the set up was for a stroke survivor, to determine which features were necessary and which were not, and to establish what nail shortening methods worked.



Figure 1. Overview of Step 'n Snip.

Based on user test results, we focused on the foot pedal clipper design, the reason being that all the other mock-ups were determined to be either unnecessary or unacceptable. Both the finger mount and finger pivot were deemed unnecessary; the mouth clipper was out of the question upon the participants' refusal to test it. It quickly became apparent that the best option to pursue was the foot pedal clipper, especially when one of the stroke survivors was able to clip his nails independently for the first time in years using the concept.

Some modifications to the foot pedal clipper included decreasing the dimensions of the base, testing different pedal styles and shapes, adding all of the improvements in the testing chart, and researching more methods for adding mobility to the nail clipper itself (such as left and right rotation).

Final Design

The final design, named the Step 'n Snip, consists of a finger nail clipper mounted on an inclined, rotatable metal rod (**Figure 1**). The clipper attaches to a foot pedal with a long steel bike brake cable, which the pedal then uses to actuate the clipper. The pedal is mounted on a base shaped such that it provides a nesting space for the clipper frame during storage; the two parts are kept together by a swiveling clip. The clipper itself is at a convenient height for users and is fitted with a nail clippings collection system.

The user can adjust the rotational angle of the clipper, if desired, using the large black knob and set screw (**Figure 2**). Then the user places or guides the desired nail to be clipped into the clipper and activates the clipper by pressing down on the foot pedal.

How the Step 'n Snip meets the user requirements

- *Clipping the strong hand.* The foot pedal allows the users to have their strong hand free to guide itself into the clipping device for an easy and efficient cut.
- *Clipping the spastic hand.* The foot pedal allows the strong hand to guide each individual finger on the spastic hand to the clipper blades. The adjustable rotation of the clipper allows



Figure 2. Design in use.

users of all levels of dexterity and spasticity to easily adjust the blades to line up with each nail.

- *Easy storage and portability.* The clipper base can be easily inserted into the pedal base and locked for compactness and easy portability. The design allows for simple, one-handed transport and manipulation of the device.
- *Weight.* The largest parts of the Step 'n Snip are plastic, therefore the device is lightweight and can be easily lifted by most users.
- *Nail collection.* The Step 'n Snip features a

modified nail collection system of a nail clipper currently on the market.

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