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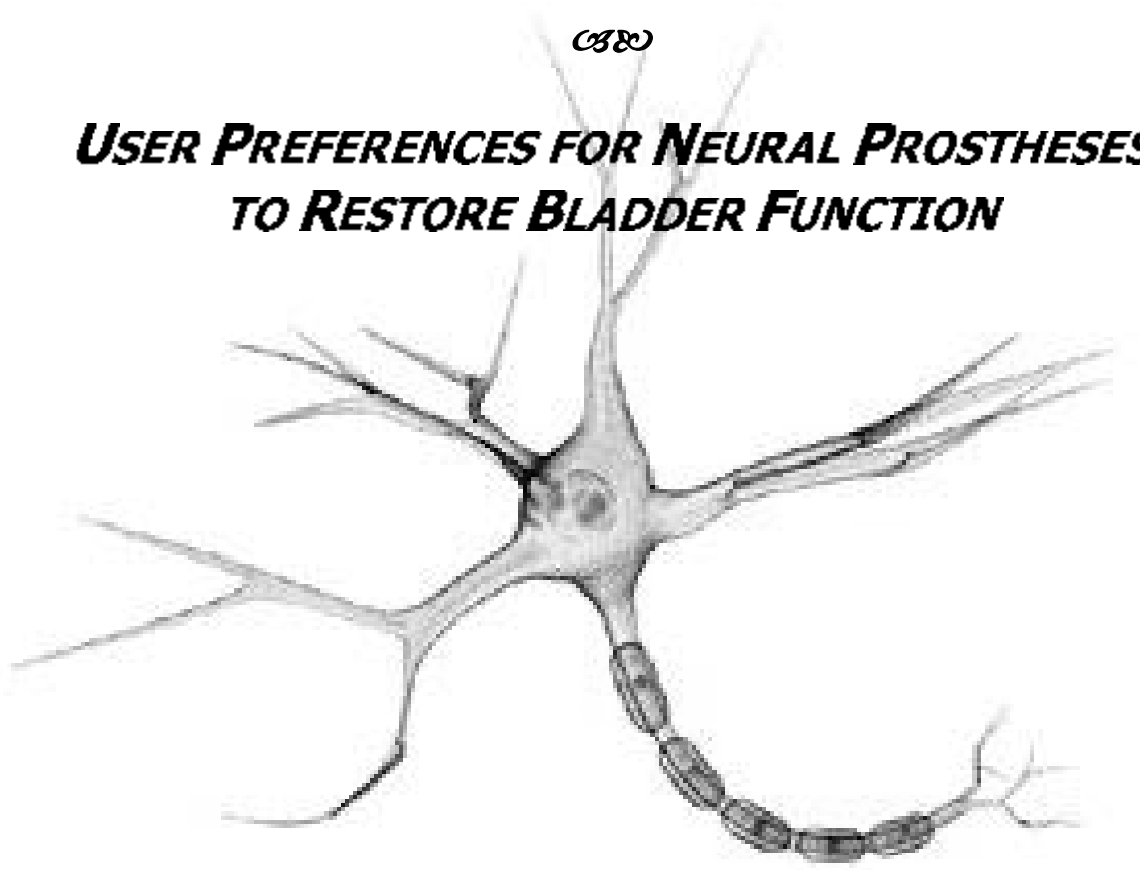
USER PREFERENCES FOR NEURAL PROSTHESES TO RESTORE BLADDER FUNCTION



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ADVICE REPORT

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ABSTRACT

Lesions of the upper motor neurons, caused by injury or disease, can leave people with bladder dysfunction, which has a major negative impact on quality of life (Westgren & Levi 1998, Snoek et al. 2004). Previous studies revealed that restoration of bladder function is highly appreciated by persons with spinal cord injury (SCI) (Anderson 2004, Snoek et al. 2005). Several different neural prosthetic solutions to restore bladder function are in development, with differing characteristics such as invasiveness, effectiveness and side effects. These characteristics can influence the willingness of patients to be treated with a certain technique. However, it is not known how these factors influence individual's choices of whether to use neural prostheses or which approach to choose. An advanced appreciation of potential user preferences can assist in device design, and will increase the acceptance of users towards these techniques.

This study was designed to determine the relative importance of different neural prosthesis characteristics from persons with SCI. A survey using a choice based conjoint analysis was used to determine utility weights for individual characteristics. Chosen characteristics for this analysis were: invasiveness, effect on continence, effect on voiding, side effects, user friendliness, and costs (willingness to pay). Three levels were set for every characteristic. Surveys were completed by persons with SCI at two academic affiliated medical systems' SCI outpatient and inpatient rehabilitation centers. 66 individuals with chronic SCI completed the survey.

Of all respondents, 19.7% did not want to have a neural prosthesis at all. Of all attributes, side effects had the largest relative importance on subject choices (.32), followed by the effect on continence (.25) and voiding (.20). A comparison of current designs revealed that neural prostheses having characteristics consistent with rhizotomy-free sacral root stimulation were preferred (48.9% first choice) over pudendal afferent nerve stimulation (45.3% second choice) and sacral root stimulation with rhizotomy (56.6% third choice). This study revealed that in their choice for a neural prosthesis, persons with SCI first focus on the side effects, and then on the effect on bladder function. Invasiveness, user friendliness and costs are less important in the decision making process. Therefore, a design with minor side effects and a major positive effect on bladder function, like the rhizotomy-free sacral root stimulation, is most likely to be accepted by persons with SCI.

CONTENTS

1. INTRODUCTION & BACKGROUND

1.1 INTRODUCTION

Paralysis caused by disease or injury of upper motor neurons can leave people without important functions like walking, using their hands, breathing and bladder or bowel function, and affects approximately 10,000 people per year in the USA alone (National Spinal Cord Injury Statistical Center 2008). Although ongoing medical research provides increasing knowledge about regeneration of the central nervous system (CNS), the complexity of spinal cord injury (SCI) is still only partly understood. Therefore, it does not seem realistic to presume that scientists will be able to induce regeneration of the injured neurons to a level that will cause a full recovery of lost functions in the near future (Prochazka *et al.* 2001). Therefore, it is more realistic to focus on techniques to artificially restore the lost functions.

A technique that can artificially restore lost functions in persons with SCI, is functional electrical stimulation (FES). With this technique, electrodes are placed in close proximity of neurons, and by sending an electrical current through the electrode, the neuron can be activated. This technique is used in neural prostheses, in which a number of electrodes are either implanted or placed on the skin. Together, these electrodes simulate a natural neural network, thereby creating the possibility to regain lost functions. Even when no functional recovery is accomplished, researchers have suggested that neural activity is important for development and recovery of neurological circuits, thereby indicating the important function of FES in neurorehabilitation (Herman *et al.* 2002, McDonald *et al.* 2002).

1.2 RATIONALE

Momentarily, a lot of research is performed to create neural prostheses that can restore a wide range of functions from hearing to walking or bladder function. The interest for neural prostheses that restore bladder function is partly fed by the finding of several studies that regain of bladder function is highly appreciated by persons with SCI (Anderson 2004, Snoek *et al.* 2005). Additionally, studies investigating the impact on the quality of life (QoL) have revealed that bladder problems have a significant impact on the QoL (Westgren & Levi 1998, Roach *et al.* 2000, Snoek *et al.* 2004). However, characteristics of neural prostheses like invasiveness and effect on bladder function differ, and it is not known what the weight of the individual characteristics is in the ultimate choice of patients for a certain technique. Since user satisfaction is an important factor for the success of an innovation, it can provide useful input for the research and design process.

1.3 AIMS & HYPOTHESES

The main aim of this project is to assess user preferences for neural prostheses to restore bladder function. This will be investigated by performing a survey among persons with SCI. To be able to design a survey that will provide useful results, first a literature study has to be performed to assure the most appropriate survey method is chosen and to determine what sample size is sufficiently large to reveal significant differences. Then a review of the literature on bladder neural prostheses will be performed to reveal the characteristics of neural prostheses that might influence the choice of users for that technique. Moreover, the opinion of experts that have contact with SCI patients will be taken into account in designing the survey. Additionally to user preferences, the attribute "costs" is included to reveal the willingness to pay.

The research question for this study is:

What are the preferences of persons with SCI regarding neural prostheses that can restore bladder function?

To find an answer on this question, the following subquestions need to be answered:

- What are the most important characteristics that differ among neural prostheses?
- How can the relative preferences for these characteristics be assessed?
- Which (combination of) characteristic(s) is the most important for the potential users?
- Do users prefer treatment with a neural prosthesis over no treatment?
- How can the preferences be implemented in the research and design process?

The survey will be performed among persons with SCI, and data will be depersonalized before analysis to guarantee protection of the privacy of respondents. By means of the result of the analysis, an advice will be formulated that will help researchers to focus on the technique that has the largest chance to be implemented successfully.

At this moment it is not known whether persons with SCI who have impaired bladder function, have a special preference for certain characteristics of neural prostheses to restore bladder function. Therefore, it is unknown which trade-offs these people make in their ultimate choice for a certain method, and researchers can not estimate whether the technique they are developing will become a success. The hypotheses to be tested are:

H_0 : There is no difference in the relative weight of characteristics of neural prostheses in the ultimate choice of the user

H_1 : There is a difference in the relative weight of characteristics of neural prostheses in the ultimate choice of the user

When this study reveals that there are one or two characteristics that are relatively important to users, scientists can focus on designing devices with the profile that corresponds to the preferences of users.

1.4 CONTEXT

This study is performed for the educational program of Health Sciences, Department of Health Technology and Services Research, University of Twente, Netherlands, and will take 6 months. The aim of Health Sciences is to combine biomedical, psychosocial, organizational and societal aspects of health, disease and health care. This multidisciplinary approach facilitates the translation of clinical research to health care and vice versa, eventually improving the care for patients.

In this study, both the latest discoveries in the area of neural prosthesis research and behavioral aspects of users will be investigated. Knowledge about users' behavior enables researchers to focus their research on the technique that is most likely to be appreciated by users, and therefore has a large chance to be implemented successfully.

2. REVIEW OF LITERATURE

2.1 SPINAL CORD INJURY

According to the National Spinal Cord Injury Statistical Center (2008), the number of persons with SCI living in the United States is estimated to be approximately 253,000, in the range of 225,000 to 296,000 persons. The main cause for SCI is motor vehicle accidents (46.9%) and most spinal cord injuries (77.8%) occur among males. The average age at injury is 38 years (National Statistical Center 2008). Non-traumatic spinal cord injuries have heterogeneous causes, and prevalence is unknown because no registries keep track of this phenomenon. However, it is estimated that the number of persons with SCI would quadruple if non-traumatic injuries were included (McDonald & Sadowsky 2002).

With traumatic SCI, primary injury is caused by traction and compression, causing fracturing and displacing bone fragments, disc material and ligaments. These particles injure both the central and peripheral nervous system. A cascade of events follows, including microheamorrhages and swelling of the spinal cord. This triggers the occurrence of secondary injury, caused by ischemia due to swelling, chemicals like glutamate released from disrupted neural membranes inducing excitotoxicity, and electrolyte shifts (McDonald & Sadowsky 2002). The exitotoxicity does not only kill neurons, but also olygodendrocytes, the nervous system main myeline producing cells (McDonald *et al.* 1998).

The level and completeness of the injured neurons determines what functions are lost. An injury above the first thoracic vertebra usually results in paralysis of all four limbs and is called quadriplegia or tetraplegia. When the level of injury is located below the first thoracic spinal level, it results in impaired or lost leg movement, and is called paraplegia. The severity of injury is covered by a five-point scale, set up by the American Spinal Injury Association (ASIA). This impairment scale can be found in figure 1. The population of persons with SCI can be distributed in two groups. Paraplegics are the persons with lower extremity motor and sensibility impairment, while tretraplegics (or quadriplegics) are persons with motor and sensory impairment of all four extremities.

Grade	Description
A	Complete; no sensory or motor function preserved in the sacral segments S4-S5
B	Incomplete; sensory but not motor function preserved below the neurological level and extending through the sacral segment S4-S5
C	Incomplete; motor function preserved below the neurological level, most key muscles have a grade <3
D	Incomplete; motor function preserved below the neurological level, most key muscles have a grade >3
E	Normal motor and sensory function

Figure 1. *Asia impairment scale*

Although many advances have been made in research to treat SCI, it is not yet possible to cure it because of the intricate neural systems responsible for function. However, research has long revealed that relatively small anatomical gains can produce major functional benefits. For instance, fewer than 10% of functional long-tract connections are needed to enable locomotion in cats (Blight 1983). In a large number of cases, this percentage of connections is preserved in white matter, though axons might be non-functional due to insufficient myelination (Falci *et al.* 1997). However, it turns out challenging to multiply the number of oligodendrocytes after SCI (Vick *et al.* 1992), and oligodendrocyte-axon interactions seem to be defect (Butt & Berry 2000). Findings like this indicate that curing SCI might be possible in the future, but many problems have to be overcome, and more research and knowledge about the mechanisms that keep the spinal cord in shape are necessary. Therefore, at present the main focus is on treating SCI, for instance by reducing (secondary) damage, and simulating lost function.

Whether a person with SCI will experience bladder and bowel dysfunction, depends on whether the lesion is confined to the grey matter, or whether it has also affected the white matter. If the lesion is confined to the grey matter, it limits motor and sensory functions to areas innervated at that level, with only slightly affecting functions below that level, like gait and bladder and bowel function. However, if the white matter is affected, even though the grey matter is spared, the person will be incontinent. In a study by the Model Spinal Cord Injury Systems of Care, 81% of patients reported to have some degree of impaired bladder function (Stover *et al.* 1995).

2.2 FUNCTION OF THE LOWER URINARY TRACT

The two most important functions of the lower urinary tract are the storage and voluntary expulsion of urine. This is accomplished by the synergistic action of different muscular structures; the bladder and the sphincters. The sphincter is comprised of the internal and external sphincter, which consist of smooth and striated muscle respectively and are innervated by different neuronal circuits. The bladder and sphincters are controlled by neural circuits, that are mainly located in the pontine micturition center in the brain stem and in the lumbrosacral spinal cord. This dependence of the urinary tract on central regulation is unique to visceral structures (de Groat 2006), and is the reason that a majority of the SCI population suffers from urinary tract dysfunction, which expresses itself as both disturbed storage and voiding (Rijkhoff 2004). Another unique feature of the lower urinary tract is its complexity (de Groat 2006), which makes treatment of lower urinary tract dysfunction challenging.

In the synergistic process of bladder and sphincter functioning, the bladder is mainly responsible for voiding, while the sphincters are responsible for continence. Both the bladder and the internal sphincter are innervated by inhibitory sympathetic fibers from the lumbar segments of the spinal cord and by excitatory parasympathetic fibers from sacral segments 2 to 4. The external sphincter is innervated by the somatic nervous system. When the bladder fills with urine and the pressure on the bladder wall increases, the smooth muscle of the bladder, called the detrusor, will contract reflexly and the internal sphincter relaxes. However, these reflexes can be inhibited by the brain until it is appropriate to urinate. At that moment, the reflexes to urinate are augmented and the external sphincter will relax. Once the urinary flow starts, it is facilitated by ancillary reflexes that reinforce bladder muscle contraction and sphincter relaxation (Bray *et al.* 1998). SCI generally results in neurogenic detrusor overactivity and detrusor-sphincter dyssynergia (Rijkhoff 2004).

To artificially induce micturition, the detrusor should be stimulated to contract. This induces the reflex loops that cause bladder emptying, while no central control is needed to continue voiding. There are four sites where stimulation results in detrusor contraction: the bladder wall, the pelvic nerves, sacral roots and the spinal cord. Among these options, sacral root stimulation has been the most successful in activating detrusor contraction (Rijkhoff *et al.* 1997, Gaunt and Prochazka 2006).

2.3 TREATMENT

Urinary tract dysfunction can result in a number of negative clinical manifestations like renal injury, incontinence and recurrent urinary tract infections. Of these effects, renal injury has the largest negative impact, and therefore the most important aim of treating neurogenic bladders is preservation of renal function. Since elevated detrusor pressure or detrusor overactivity is the most important risk factor for renal dysfunction (Gerridzen *et al.* 1992), the aim of treatment is to retain a low pressure in the bladder.

Treatment for overactive bladder first consists of pharmacological therapy using anti-muscarinic agents. Since detrusor contraction is largely regulated by muscarinic receptors, blocking these receptors causes less frequent and less forceful detrusor contractions (Rijkhoff 2004). However, pharmacological treatment often has side effects. Moreover, this treatment often has to be combined with clean intermittent catheterization, and a number of studies have revealed that catheterization has a large negative impact on the QoL (Oh *et al* 2005, Oh *et al.* 2006). The study by Oh *et al.* (2006) also suggests that there is a correlation between the level of independence and depression.

For patients that do not respond to conservative therapy, there are several alternative therapies like injections of botulin toxin in the detrusor muscle, detrusor myectomy and dorsal sacral rhizotomy. Another option, which does not require irreversible surgery is the use of a neural prosthesis. Since artificial stimulation of neurons is the treatment that most closely resembles healthy bladder function, the use of neural prostheses is the ultimate treatment to restoring bladder function.

2.4 NEURAL PROSTHESES

A neural prosthesis is a technology that uses FES of the nervous system to restore function for individuals with neurological or sensory impairment, and consists of either external or implanted devices. By means of the electrical stimulation, the action potentials that normally cause the activation of tissues are simulated. This artificial generation of action potentials is the basis for all neural prostheses.

The first portable neural prosthesis was utilized by Liberson et al. in 1961 to provide hemiplegic patients control over their foot movement (Liberson & Holmquist 1961). Since that time, neural prostheses have been developed for a wide range of applications, like a spinal cord stimulator to treat intractable pain and motor disorders, and auditory nerve stimulator to restore hearing, a deep brain stimulator to treat tremor, a vagal stimulator to treat intractable epilepsy, and a sacral nerve stimulator to control bladder emptying, and over 230,000 have been implanted (Rijkhof 2004).

Neural prostheses are generally very similar in design and purpose. The large difference is whether electrodes are placed on the skin, under the skin or whether they are placed directly around or adjacent to the nerve with implanted leads. Neural prostheses consist of a portable power source, control unit, stimulator, lead wires, electrodes and sensors (Gonzalez *et al* 2001), and the electrodes can be placed anywhere along the nerve. A disadvantage of electrical stimulation of nerves is that the sensory fibers are also stimulated, so if sensation is preserved this can result in pain.

Although an implanted neurostimulator most closely resembles reality since it is hardly noticed to be there, most neural prostheses are transcutaneous stimulators with electrodes that are placed on the skin. This kind of neural prosthesis is especially popular because it is non-invasive and relatively cheap compared with other types of neural prostheses. However, since the electrodes are not in close proximity of a neuron, this method is less specific than when an electrode is placed around a neuron, and a relatively high current has to be used which makes it less suitable for daily use (Ragnarsson 2008).

2.4.1 NEURAL PROSTHESES AND BLADDER DYSFUNCTION

Several studies have been performed to investigate the preferences of persons with SCI regarding restoration of function (Anderson 2004, Snoek *et al.* 2004, Snoek *et al.* 2005). Quite surprisingly, these studies revealed that out of a number of possible functions, restoration of bladder and bowel function was even more important than restoration of walking movement. Especially for persons with paraplegia, restoration of bladder function is of high importance.

A wide variety of neural prostheses is being developed at this moment. Methods that are used differ, and can consist of intravesicle stimulation, transcutaneous stimulation, stimulation of peripheral nerves or sacral roots and stimulation of the spinal cord (for an overview, see Gaunt & Prochazka 2006). The technique most commonly used to restore bladder dysfunction is the sacral anterior root stimulator, and implementation is often accompanied with dorsal sacral root rhizotomy. This eliminates neurogenic detrusor overactivity (NDO) and therefore results in an increased bladder capacity (Rijkhoff 2004). Stimulation of the efferent nerves by the NP produces a contraction of both the detrusor and the sphincter muscle. Voiding is possible upon intermittent stimulation, because the striated muscle of the sphincter contracts and relaxes more rapidly than the smooth muscle of the detrusor (Creasey 1993). However, the dorsal rhizotomy results in permanently lost sexual sensation, lost reflex erections and loss of self-induced defecation, which makes that a lot of individuals choose not to have this treatment.

Currently, a number of different neural prosthetic approaches are in development by various research groups and companies. The main difference between these approaches is interface location. Some research groups focus on peripheral stimulation, for instance stimulation of the pudendal nerve (Boggs *et al.* 2006, Bruns *et al.* 2008, Peng *et al.* 2008). Others focus on sacral root stimulation, either combined with rhizotomy to abolish hyperreactive bladder and sphincter contractions (Brindley 1994), or combined with non-rhizotomy options like high-frequency pudendal nerve block (Boger *et al.* 2008). There also is a number of groups that focuses on surface approaches (for an overview, see figure 2).

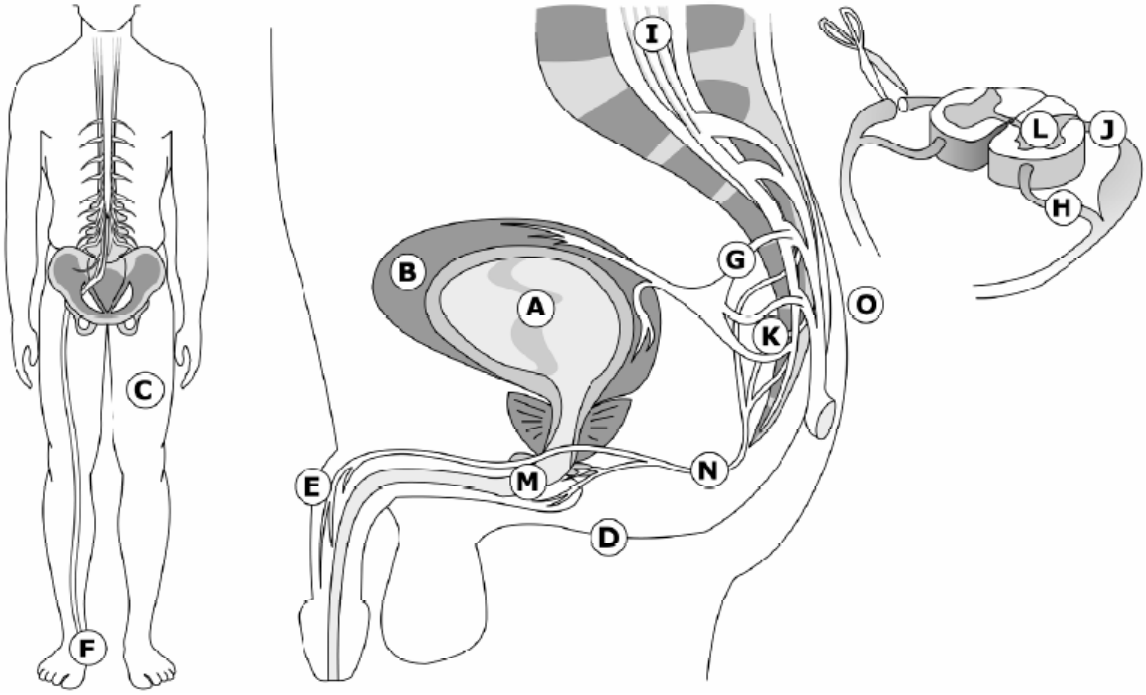

Figure 2. *Electrode locations for controlling the lower urinary tract. (A) Intravesical, (B) Bladder wall, (C) Thigh, (D) Pelvic floor, (E) Dorsal penile nerve, (F) Tibial nerve, (G) Pelvic nerve, (H) Intradural sacral anterior root, (I) Extradural mixed sacral root, (J) Intradural sacral posterior root, (K) Sacral nerve, (L) Spinal cord, (M) Intraurethral, (N) Pudendal nerve, (O) Sacrum.* Source: Gaunt & Prochazka 2006

2.4.2 CURRENTLY AVAILABLE

The neural prostheses that are currently available for persons with bladder dysfunction are the Finetech-Brindley Bladder system (Finetech Medical, UK), also known as Vocare, and the InterStim Therapy (Medtronic, USA). The Vocare system (see figure 3) induces detrusor contraction by stimulating the sacral anterior nerve roots (S2-S4). Indications include ASIA level A, a suprasacral spinal cord lesion, or intact peripheral bladder innervations. This method of stimulation improves voiding, thereby overcoming the need to use catheters. However, stimulation of these nerves also induces contraction of the external urethral sphincter, which hinders complete voiding. This problem can be overcome by applying intermittent bursts of stimulation, alternated with short periods without stimulation. This pattern of stimulation will cause the detrusor to stay contracted, while the sphincter can get into a state of relaxation (Brindley *et al.* 1982). Implantation of the Vocare device is

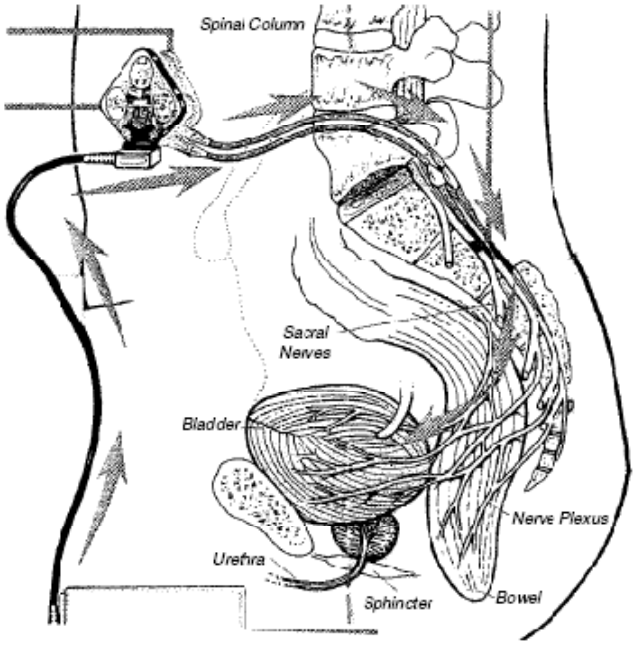

Figure 3. *Finetech Brindley device (Vocare).* Source: Ragnersson 2008

usually combined with posterior dorsal rhizotomy (S2-S5) to decrease detrusor and sphincter dyssynergia and lower the risk of autonomic dysreflexia. However, this rhizotomy is also associated with irreversible loss of reflex erection and ejaculation (Creasey *et al.* 2001). Although about 70% of males using Vocare can have an erection with a different pattern of stimulation (Egon *et al.* 1998), rhizotomy makes this procedure less appealing to the patients.

Another kind of neural prosthesis, the Interstim Therapy, uses neuromodulation to improve continence. This device uses low frequency stimulation to continuously contract the sphincter, thereby inhibiting detrusor contraction. Because the electrodes are placed extradurally, the procedure to implement this device is less invasive as the Vocare device. Moreover, no rhizotomy has to be performed.

In short, the clinically available neural prostheses have different characteristics like the side effects that are due to rhizotomy, and the effect on bladder function. Moreover, the devices that are currently in the design process cover an even broader range of characteristics. However, it is not known what characteristics are the most important for the eventual users of the devices. Knowledge about user preferences enables researchers to adapt the neural prosthesis design process to user preferences, thereby increasing the chance of successful implementation.

3. ANALYSIS USER PREFERENCES

3.1 INTRODUCTION

A number of studies revealed that persons with SCI highly prioritize restoration of bladder function (Anderson 2004, Snoek *et al.* 2004, Snoek *et al.* 2005). To take this observation to the next level, this study is going to investigate the relative importance of different characteristics to the SCI population in their choice of methods to restore bladder function. The emphasis will be on methods using FES, since these methods, as opposed to mechanical instruments like catheters, are able to actually restore bladder function instead of dealing with the effects.

Since it is not known to developers of neural prostheses to what level the characteristics of a device or accompanying procedure determine the choice of persons with SCI, they might ultimately develop a technique that fails to be implemented successfully, because its characteristics do not correspond to user preferences. This study can make developers aware of user preferences, so they can devise the path of development towards an optimal level.

The analysis was performed in two hospitals in Cleveland, which both have an extensive SCI patient population. These hospitals are the MetroHealth Medical Center and the Louis Stokes VA Medical Center.

3.2 CHOICE OF RESEARCH TOOL

3.2.1 TYPES OF MARKET RESEARCH

To reveal the user preferences for a given method or technique, a method can be used that originated in market research, but is now widely used to valuate public goods or care plans. There are two ways to investigate user preferences: by means of exploratory or confirmatory research. Exploratory research is performed to discover and get a broader vision, while the goal of confirmatory research is resolution and narrowing of options (McQuarrie 2006, p6).

Another distinction in preferences studies is between market intelligence and research studies. Market research studies are studies bounded in space and time and linked to a specific project, whereas market intelligence is an ongoing activity not bound to a specific project (McQuarrie 2006, p7).

3.2.2 STAGE IN DECISION CYCLE

To make sure the most appropriate method is used to reveal user preferences regarding a bladder neural prosthesis, the decision cycle described in McQuarrie (2006, p26) is used. This decision cycle exists of four stages: scanning of the environment, generation of options, selection of an option and evaluation of success. To be able to choose the most appropriate research technique, it has to be determined in what stage of the decision cycle this study will be performed.

The scanning of the environment and generation of options are both performed in previous studies. As mentioned before, a study by Anderson (2004) has revealed that restoration of bladder function is regarded highly important by the SCI population. Other studies have revealed that there are numerous options to manage urinary tract dysfunction, discussed in a recent review of Gaunt & Prochazka (2006). While mechanical instruments generally do not restore urinary tract dysfunction, but only help to manage the effects, methods that use FES have the ability to restore bladder function. The different methods of FES differ in characteristics like invasiveness and effectiveness. However, it is not clear what the relative importance of these characteristics is in the decision of targeted users. While the studies of Anderson (2004) and Gaunt & Prochazka (2006) cover the steps 'scanning of the environment' and 'generation of options', the next step in the decision cycle is to select an option. This can be achieved by ranking the relative importance of the characteristics that differ between different methods, thereby revealing the preference of users.

3.2.3 RESEARCH OBJECTIVE

With the help of the decision cycle, it has been determined that the goal of this study will be to reveal the weighting of characteristics of bladder neural prostheses, thereby revealing the preferences of the SCI population for this technique. The objective of this study is therefore to rank the importance of characteristics of neural prostheses for persons with SCI regarding the restoration of bladder function, by means of which the most appealing design can be determined.

3.2.4 RESEARCH TOOL

From table 2.4 in the book of McQuarrie (2006), it becomes clear that there are four possible methods to use in the 'select an option' stage of the decision cycle: secondary research, survey research, choice models and experiments. Secondary research is not an option for this study, since data regarding users preferences for the restoration of bladder function are not available. Of the remaining three options, choice models seem to be the most appropriate method to use in this study, since they are designed to generate a model of how a consumer makes a choice among various product offerings available. This tool therefore seems to be useful in achieving the research objective.

Choice modeling is a form of confirmatory research. This characteristic of choice modeling is another factor that confirms that this method can be used to achieve the research objective, since the objective of this study is to focus the design process towards the product that has the largest chance of success, and this also is the goal of confirmatory research. Because bundles of characteristics of the product are put forward to the user, a more realistic model can be determined than when the user would simply be asked to rank the characteristics, for example in a survey. Moreover, this method of choice modeling has lately gained popularity in health care research, suggesting this method is suitable to investigate user preferences in health care-related issues like restoration of bladder function (Ryan 2004, Ryan *et al.* 2001).

3.3 CHOICE MODELING

From the previous section it has become clear that choice modeling is the most appropriate method to achieve the research objective of this study. The assumption made in choice modeling is that any product can be conceptualized as a bundle of characteristics (attributes) that ultimately determine the choice of a potential user to choose for that particular product or to choose an alternative. The strength of this method is that it can identify the complex procedure of making a choice. Clearly, it is difficult for people to thoroughly explain how they weigh and integrate the relative importance of various attributes. In choice modeling, it can be analyzed what consumers do in a carefully constructed situation, rather than what they say. There are several choice modeling techniques, but the common characteristic is that they all provide a model of the importance of each attribute in the decision of a (potential) user.

3.3.1 METHODS

Three methods of choice modeling are conjoint analysis, direct weighting of attribute importance, and analytic hierarchy process (AHP) (McQuarrie 2006, Mulye 1998). In a conjoint analysis, products are presented as bundles of characteristics and the analysis decomposes the resulting judgments into estimated individual-level part worth utilities for the individual attributes (McQuarrie 2006, p155). The bundles consist of both real as well as hypothetical profiles (Gustafsson *et al.* 2001, p7). The principal value of conjoint analysis is to indicate the trend in preferences of consumers for competing products (Mulye 1998).

Direct weighting of attributes importance works in exactly the opposite direction. This method is started with direct ratings or ranking of characteristics of existing products, thereby examining the requirements for success for a new product. However, to be able to rate how effectively a particular product delivers the characteristics, participants must be familiar with the products.

AHP is a technique that can be described in three steps: In the first step, the hierarchy is structured by decomposing the problem into levels of criteria, subcriteria, and options under consideration. In step two, pairwise comparisons are put forward to determine priorities. In the last step, the weights are determined by multiplying the priority of the lower-level criteria with the higher-level criteria. In this way, the alternatives can be ranked. This method has been mostly used to improve the quality of a decision by getting accurate judgments from the decision makers, by providing feedback on how consistent their decisions are (Mulye 1998). AHP can only be administered on a computer, since part of the method is to provide direct feedback to the respondent about the consistency of judgment.

Of the three methods discussed in this section, conjoint analysis is the most suitable for this study, because the aim of the study is to reveal trends in preferences for bladder neural prostheses. Moreover, direct weighting cannot be used, because potential respondents from the target group of persons with SCI might not be familiar with bladder neural prostheses. Also, AHP is not suitable for two reasons: The goal is not to provide feedback on consistency of decision making, and the questionnaire will be performed at multiple sites with an option for respondents to take the survey home, and therefore has to be in the mode of a paper and pencil survey.

3.4 CONJOINT ANALYSIS

Conjoint analysis is also known as discrete choice experiments or choice format stated preference survey. There are several possibilities to present the stimuli, including using a point scale for every individual characteristic (rating), ranking the order of combinations or let test persons choose between two combinations. The main types of conjoint techniques are:

Full factor evaluation: The respondent receives cards with all different combinations of attributes. After sorting these cards, the respondent rates each card on a scale of 0-100 (Green *et al.* 2001).

Compositional techniques: The respondent first rates the levels on a 0 to 100 scale, and then rates the attributes on an importance scale (Green *et al.* 2001).

Conjoint value analysis (CVA): This method uses full product profiles, of which pairs are shown to the respondent. The respondent then has to rank the profiles (Carmone and Schaffer 1995).

Hybrid techniques: This method combines the compositional technique with a method that uses combinations of attributes (Gustafsson *et al.* 2001, p15). This technique asks the respondent to perform two tasks: a task using compositional technique and an evaluation of a subset of the full-profile tasks (Green *et al.* 1981).

Adaptive Conjoint Analysis (ACA): This method is viewed as a modern, computer-aided form of the two-factor method. Questions asked are adapted to the previous answers of respondents (Gustafsson *et al.* 2001, p15). Each respondent first performs a self-explications task and then evaluates some combinations that consist of two to three attributes (partial product profiles), two at a time (Johnson 1987).

Choice based conjoint (CBC): This method simulates a choice environment, thereby making it the method with the largest degree of reality. Instead of ranking profiles or attributes as in other methods of conjoint analysis, in CBC respondents have to choose one profile out of two or more (Berneburg and Horst 2007). This method of conjoint analysis has gained a lot of interest in the last couple of years (Hartmann and Sattler 2002), and has proven to be reliable as long as the number of profiles does not exceed thirty (Green and Srinivasan 1990). By means of this method, trade-offs can be quantified for choices that include aspects of process as well as outcome (Marshall *et al.* 2007).

A study by Hartmann and Sattler (2002), investigating the use of conjoint analysis in Germany, Austria and Switzerland revealed that CBC is the most used method (47%), followed by ACA (34%) and CVA (20%). For this study, a type of conjoint analysis that uses ranking of attributes is preferred, because studies have revealed that ranking of attributes outperforms methods that use rating of attributes on the criterion of predictive validity (Mulye 1998). To simulate the situations in which people make decisions about neural prostheses to an as realistic extend as possible, and because researchers have suggested that a ranking procedure might be more reliable than the rating scale in conjoint method, a CBC will be used in this study. Because the analysis is performed at different locations and by different persons, it will be provided as a paper and pencil survey.

Devising a conjoint analysis involves seven steps. Different authors give differing interpretations to the 7-steps flow model that was first put forward by Green and Srinivasan in 1978. The steps described here are a combination of the steps proposed by Gustafsson *et al.* (2001) and McQuarrie (2006).

3.4.1 STEP 1 - ATTRIBUTES

In the first step, the characteristics that influence the users' choice have to be identified. Experts recommend using no more than 6 attributes for a conjoint analysis (Green and Srinivasan 1990, Hartmann and Sattler 2002). This limit is set to prevent to overload a respondent with too many questions, thereby increasing the chance that the respondent will start using simplified decision rules, resulting in a distortion of their preference profile.

For this study, the most important characteristics of neural prostheses to the users have been determined by literature research, careful consideration with specialists in the field of SCI and rehabilitation, researchers operating in the field of neural prostheses and persons with SCI. The attributes chosen are:

- Invasiveness
- Effect on continence
- Effect on voiding
- Side effects
- User friendliness
- Costs

Invasiveness has been chosen because a surgical intervention or interface location might affect the willingness of patients to be treated. Since a positive outcome is the main determinant to be treated, effect on continence and effect on voiding have been included in the survey. These attributes have been separated, because the different treatments affect these outcomes differently. The attribute side effects has been chosen to be able to compare a treatment with rhizotomy to other treatment options. User friendliness has been chosen because the treatments differ in the level of independence the patients will have after the treatment. For instance, for some neural prostheses communication with an external device is needed to activate the neural prosthesis, while for others the patient can just push a button to activate the device. The costs attribute will function as a method to analyze willingness to pay, and has been defined as out of pocket costs, so the amount patients have to pay for the treatment additional to reimbursements from health insurance.

3.4.2 STEP 2 - LEVELS

The second step involves determining the number of levels for each characteristic. In this step it is important that all relevant levels are taken into account, while abundant levels should be left out of the analysis. It has to be kept in mind that the levels should not be too far apart, nor should they be too close. Moreover, there is a limit to how many permutations you can ask someone to judge. This limit indicates that not all possible prosthetic solutions can be put forward in this CBC. Since the most appealing option for patients is to have a permanent solution, the focus of this study is on permanent devices. Therefore transcutaneous stimulation is not taken into consideration. The main focus of the survey is on methods that use stimulation of the pudendal nerve, or stimulation of the sacral roots, either with rhizotomy or with an alternative for rhizotomy, because these designs seem most promising to restore bladder function.

To keep the analysis unbiased, the number of levels for each attribute should ideally be the same, since it has been shown that when an attribute has more levels it becomes more important (Wittink *et al.* 1991). Since the devices of interest only provide two levels for invasiveness – stimulation of pudendal nerve or sacral roots – while other attributes all have three levels, the level of subcutaneous electrodes is added to the attribute invasiveness.

The levels of costs have been determined by asking persons with SCI how much they would be willing to pay extra for treatment with a neural prosthesis, knowing that there is a prosthetic solution that will be fully covered by insurance, but has a high level of invasiveness and might not have an optimal outcome. This approach has been chosen because it is realistic that health insurance will cover a standard treatment with a neural prosthesis. The outcome of this approach was that persons were willing to pay about $250 out of pocket for a treatment that is not fully covered by health insurance. To measure the willingness to pay, the levels of the attribute costs are therefore set at a level below this threshold and a level above the threshold. The ultimate list of attributes with their levels is shown in figure 4.

Invasiveness

1. Electrodes placed under skin, no hospital admission
2. Electrodes implanted in surgery via buttocks, 1-3 days hospital admission
3. Electrodes implanted through surgery in lower part of your spinal cord, about 1 week hospital admission

Effect on continence

1. Complete continence, no more accidents
2. Improved continence, but still occasional accidents
3. No effect on continence or number of accidents

Effect on voiding

1. Complete voiding, no catheterization needed
2. Improved voiding, but catheter still needs to be used sometimes
3. No change in amount of urine you can void

Possible side effects

1. No side effects
2. Side effects may include occasional discomfort
3. Side effects include permanently lost sexual sensation, no reflex erections and no self-induced defecation

User friendliness

1. No external device needed to activate neural prosthesis, battery has to be changed every 5 years with minor surgical intervention
2. No external device needed to activate neural prosthesis, device has to be recharged by yourself every day/week
3. External device needed to activate neural prosthesis and has to be recharged every day/week

Costs

1. none
2. $ 150
3. $ 400

Figure 4. *List of attributes with their levels*

3.4.3 STEP 3 - SCENARIOS

The third step is to make different combinations with all attributes. To keep the number of combinations, and therefore the number of questions in the questionnaire within a reasonable range, while still ensuring efficient statistical estimation, it is possible that a reduced design needs to be used.

For this study, SSI web by Sawtooth Software is used to set up the survey. This software is especially designed to create conjoint analyses, and also has the option to create a CBC. It creates the optimal design for the survey using a fractional factorial design, so therefore it is not necessary to perform reduced design processing.

3.4.3.1 FIXED SCENARIOS

Additional to the random scenarios with hypothetical profiles created by the software, some fixed scenarios, also called holdout scenarios, are added to the random scenarios created by the survey. Fixed scenarios can be useful in conjoint analysis because:

- They provide a proximal indication of validity, measured by the utilities' ability to predict choices not used in their estimation
- They provide a check on the scaling of utilities. If the most popular concepts are overpredicted, then the scale parameter should be reduced. If the predictions are too flat, then the scale parameter should be increased.
- They permit identification and removal of inconsistent respondents
- They can be used for testing specific product configurations under consideration. Much value can be added by direct measurement of these concepts
- They can be used for testing the accuracy of market simulators. They aid considerably in comparing alternative models (logit, latent class, ICE, or HB) and choice simulation strategies.
- If holdout concepts have been defined with differing degrees of product similarity, they can be used for tuning the appropriate correction for product similarity in Randomized First Choice modeling

Three fixed scenarios (scenario #5, #10 and #15) are added to compare the preferences for three kinds of non-hypothetical neural prostheses: a sacral root stimulator combined with rhizotomy, a sacral root stimulator with an alternative for rhizotomy, and a pudendal nerve stimulator. So these scenarios will be used to test the product configurations under consideration and function as an indication of validity, thereby making the survey design more efficient.

Another fixed scenario is added to check for consistency in the response (question # 12). This check tests the rationality of choices made. When the levels of all other attributes are equal, it can be assumed that respondent prefer a positive effect on continence or voiding over no effect at all. Also the previously mentioned fixed questions with the non-hypothetical neural prostheses will be used for a consistency check. These questions should result in a ranking of the neural prostheses. If the subject seems to have answered the questions randomly, this is considered inconsistent. If subjects fail both inconsistency checks, they will be dropped from the analysis.

3.4.3.2 CREATING AN EFFICIENT CBC

Other important criteria for designing an efficient CBC implemented in the software are level balance, orthogonality, minimal overlap, and utility balance (Huber & Zwerina 1996). Level balance is the requirement that the levels of an attribute occur with equal frequency. Orthogonality is satisfied when the joint occurrence of any two levels of different attributes appear in profiles with frequencies equal to the product of their marginal frequencies. However, this criterion can conflict the criterion of level balance, thereby complicating the process of setting up an efficient design, as with this study. Two characteristics of this study design made that the level balance and orthogonality became conflicting: the limited number of questions in order not to overload the subjects, and the limited use of different versions, because the survey will be provided by paper and pencil. The design of this study consists of 14 random scenarios and two versions, so a total of 28 scenarios with two profiles each. Since every attribute has 3 levels, all levels should occur exactly one-third of the cases, but with 56 profiles this is not possible.

On the other hand, according to the orthogonality criterion a certain combination of two criteria must occur in one-ninth of cases. However, the 28 scenarios of this study do not provide an exact one-ninth percentage. So neither perfect level balance nor perfect orthogonality is proceeded in this study. This goal could be reached by increasing the number of random scenarios to 18, but with the four fixed scenarios this would result in over 20 questions, which would make the survey too long. However, because both the level balance and orthogonality criterion are only off by one scenario or profile, nearly perfect level balance and orthogonality are reached with this number of questions. Additionally, Kuhfeld *et al.* (1994) state that orthogonality should not be the main goal of design creation, and the more a design tends towards balance and orthogonality, the more efficient the design is.

Minimal level overlap means that the probability that an attribute level repeats itself in each choice set should be as small as possible, and should be taken into account since profiles with the same levels for different attributes do not provide much information. Utility balance means that there should be a balance in the most favorable and least favorable levels of a profile, thereby not exclusively favoring one profile over another. These four aspects mentioned in the article by Huber and Zwerina (1996) are taken into account when designing the survey using SSI web.

3.4.4 STEP 4 - PRESENTATION

In step four, the method in which the stimuli are presented has to be determined, as well as the characteristics of the sample of the population that is going to be tested. It is important to make sure that the sample is sufficiently-sized and represents the whole population of interest. This will reduce the sample error.

An aspect that determines sample size is the total population of interest. According to the National Spinal Cord Injury Statistical Center (2008) 225,000 to 296,000 persons in the United States have SCI, with an average of 253,000 and an incidence of approximately 40 cases per million each year. Although this information reveals that the estimation of the number of persons with SCI is not very accurate, the fact that the population is larger than 5,000 individuals indicates that in calculating the sample it can be presumed that the population is infinite (Orme 1998).

For CBC, a rule of thumb can be used to calculate the sample size. This rule makes use of the knowledge that choices are discrete 0/1 data, and rules for computing confidence intervals for proportions are well defined. Also, there is a balance between letting a large number of respondents answer a small number of questions, and letting a small number of respondents answer a large number of questions. It has been shown that as long as enough respondents are included to represent the population adequately, doubling the number of tasks they complete is about as good as doubling the sample size in terms of reducing error (Johnson & Orme, 1996). This said, the following rule should be used to calculate the sample size, assuming the population is infinite:

$nta/c \geq 500 \Rightarrow n = 500c/ta$

Where: n= number of respondents
t = number of tasks
a = number of alternatives per task (not including the 'none')
c = number of "analysis cells"

C is equal to the largest number of levels for any attribute when only the main-effects are considered. However, when two-way interactions between variables are also investigated, c is equal to the largest product of levels of any two attributes (Orme 1998). Since this study aims at getting a first impression of the market, only the main-effects will be investigated. Therefore the calculation of sample size for this study will be:

t = 14
a = 2
c = 3

$$n = 500 \frac{3}{14+2} = 54$$

This sample size is consistent with the guideline put forward in the article by Orme (1998) that for investigational work and developing hypotheses about a market, between 30-60 respondents will do. The first sample of 20 respondents indicates that about 25% of the subjects has a dominant preference not to have a neural prosthesis, and 5% does not pass either consistency test. Since the focus of the research will be on persons that are willing to have a neural prosthesis, the sample size is increased by 30% and a safety factor of 15%, making the total sample size 79.

3.4.4.1 SAMPLING METHODS

There are different sampling methods, which are either classified as probability or nonprobability sampling (McQuarrie 2006, p95). In probability sampling, each test subject has a known non-zero chance of being selected, while in nonprobability sampling test subjects are selected in a non-random manner. The largest difference between these two classes of sampling methods is that the sampling error can be calculated in probability sampling, whereas the sampling error remains unknown in nonprobability sampling. In figure 5 an overview of all sampling methods can be found.

Probability samples
Random sampling: This is the purest form of probability sampling. Each member of the population has an equal and known chance of being selected.
Systematic sampling: This method is also called the Nth name selection technique. After calculation of the required sample size, every Nth record is selected from a list of population members.
Stratified sampling: This technique reduces sampling error. A stratum is a subset of the population that share at least one common characteristic. Relevant stratums are identified after which random sampling is used to select a sufficient number of subjects from each stratum. Often used when one or more of the stratums in the population have a low incidence relative to the other stratums

Nonprobability sampling
Convenience sampling: This method is generally used when there is an interest in an approximation of the truth, since the test subjects are chosen because that sample is convenient.
Judgement sampling: As the name implies, this method is based on judgement, for example the entire sample from one "reprisentative" city.
Quota sampling: This method is the nonprobability equivalent of stratified sampling. Stratums are identified, after which convenience or judgement sampling is used.
Snowball sampling: This special nonprobability method is used when the desired sample characteristic is rare. It relies on referrals from initial subjects to generate additional subjects. However, this method of sampling introduces bias.

Figure 5. *Overview of all sampling methods (McQuarrie 2006)*

The sampling error in probability sampling can be reduced by simply increasing sample size, while the sampling error in nonprobability sampling can only be reduced to a certain point (Orme 1998). Although it is generally desired to reduce the sampling error as much as possible, and therefore use probability sampling, this study aims to reveal only an approximation of user preferences. Because test subjects will be approached by physicians or nurses when they are in the hospital for an appointment, a convenience sampling method will be used.

Before participating in the survey, it has to be made sure that the patient understands the intention of the survey. The understanding of the patient will be established by means of an interview and by letting the patient fill out the example scenario, since all levels in this scenario favor the choice of the second alternative. If the interview or example indicates the subject does not understand the survey, this person does not have to fill out the survey. Another important aspect is that personal data have to be protected. Because of this, the patient has to sign an informed consent and authorization form set up according to HIPAA rules, which can be found in appendix 2 and 3.

3.4.5 STEP 5 – JUDGMENT PROCEDURE

In step five, it has to be decided what kind of rating or judgment procedure will be applied. Since it has been decided in step 4 that a CBC will be used for this study, this implies that respondents are asked to choose between a certain number of different profiles. To keep the survey comprehensive for respondents, they will be asked to make a choice between two alternatives. To maximize the information obtained with this survey, the respondents will then be asked to choose between the preferred treatment, or no treatment at all (Marshall *et al.* 2007). This method is also referred to as the "dual-response none" method, and is an indicator for the overall preference for the product category under research (Oppewal & Timmermans 1993).

The software used to create the survey also has the option to set "prohibited pairs", and this function is used to create the prohibited pair "no effect on continence or number of accidents" and "no change in the amount of urine you can void". This combination is prohibited, because it would not make sense for persons undergoing surgical procedures or paying for a procedure while there is no effect on either continence or voiding, thereby making the other scenario the most probabilistic to be chosen. This would give overrated part worth utilities to the attributes "effect on continence" and "effect on voiding", thereby biasing the results.

Using the Sawtooth Software, two versions of the survey are created to minimize order effects. The survey contains 18 scenarios: 14 random scenarios, 3 scenarios comparing three kinds of neural prostheses that are currently available or in the design process, and 1 additional scenario to check for consistency. Additionally, some demographic questions are asked to be able to determine possible subgroups. The survey can be found in appendix 1.

3.4.6 STEP 6 – STATISTICAL ANALYSIS

After execution of the questionnaire, there are two more following steps. First, a statistical analysis has to be applied to determine utility weights for each individual attribute. This analysis will relate differences in expressed preferences of combinations of attributes back to the relative importance of a single characteristic. This analysis will also reveal nonlinear preferences, which reflect the situation in which the preference for that characteristic is greatest at its middle level.

3.4.6.1 HIERARCHICAL BAYES

Individual utility weights will be calculated using Hierarchical Bayes. The Bayesian analysis provides estimates of individual part worths using data from other respondents and the principle of conditional probability.

The hierarchical model is based on two levels; a high level at which it is assumed that individual's part worths are described by a multivariate normal distribution, and a lower level at which it is assumed that the individual probabilities of choosing particular alternatives are governed by a multinominal logit model. From the individual utility weights, the average utility weights are calculated for each level.

The dual-response none option is analyzed as an independent choice task in the Hierarchical Bayes. This indicates that first the choice task without the 'none'-option is analyzed, followed by the same choice task with a 'none' option. Failure to pick the 'none' alternative in the second stage results in a redundant task. In this way, both the preference of the respondent for a certain option and the preference to actually acquire the product are revealed.

3.4.6.2 THE LOGIT MODEL

The average utilities will be analyzed using the logit model, which is based on the discrete choice model. This model considers choices to be discrete, involving an "either-or" situation. The choice the individual ultimately makes depends on the characteristics of the choices, their relative importance, and personal preferences. There are different types of discrete choice models: the linear probability model, the probit statistical model and the logit model. The linear probability model however, has the flaw that the calculated probability is not always in the [0,1] interval. The probit statistical model and logit model both overcome this problem, and give approximately the same results. The logit model differs from the probit model only in the cumulative distribution function that is used to define choice probabilities (Griffiths *et al.* 1993, p751). Of these models the logit model is somewhat easier to use because it does not involve an integral, whereas the probit statistical model does. So for this study, the logit model will be used to analyze the data obtained by the conjoint analysis.

For the logit model, the choice probability is given by:

$$P_i = F(I_i) = F(\beta_1 + \beta_2 x_{i2} + \ldots + \beta_K x_{iK}) = F(x_i'\beta)$$

Where P_i is the probability index, I_i is utility index, x_i is the difference in characteristics between two options, β is the relative importance for each characteristic, and $F(\cdot)$ is the cumulative distribution of a logistic random variable, given by

$$P_i = F(x_i'\beta) \qquad \frac{1}{1+e^{-x_i'\beta}}$$

The average part worth utilities will be determined using the SMRT program of Sawtooth Software. This program is especially designed to analyze conjoint data, using a simulator regression model based on aggregate-level logit. This logit will allow calculation of the predicted choice probabilities for any assumed neural prosthesis. Subjects with a dominant preference not to have a neural prosthesis will be analyzed separately.

Following the analysis, the preferences for every attribute will be visualized by plotting on a scale from 0 to 1, like in the study by Marshall *et al.* (2007). This will provide a graph for each attribute, in which the slope of the graph reflects the relative importance of each attribute.

The model used for the analysis is based on the following assumption:

$$P_{iNP} = \beta_1 + \beta_2 x_{i2} + \beta_3 x_{i3} + \beta_4 x_{i4} + \beta_5 x_{i5} + \beta_6 x_{i6} + \beta_7 x_{i7}$$

Where P_{iNP}= the probability to choose for a neural prosthesis
β = the part worth utility of each attribute
x_{i2} = Δ Invasiveness
x_{i3} = Δ Effect continence
x_{i4} = Δ Effect voiding
x_{i5} = Δ Side effects
x_{i6} = Δ User friendliness
x_{i7} = Δ Costs

When all attributes have the same number of levels, like in this study, the values of the estimated partworths give an indication of the relative importance of all attributes (Gustafsson *et al* 2001, p 348).

3.4.6.3 INDEPENDENCE FROM IRRELEVANT ALTERNATIVES

The aggregate logit model used in this analysis is affected by Independence from Irrelevant Alternatives (IIA), also known as the "Red-Bus/Blue-Bus problem. The basic idea of IIA is that the ratio of any two products' shares should be independent of all other products. However, in the real world, products compete unequally with one another, and when an existing product is improved, it usually gains most from a subset of products with which it competes most directly.

The example mostly used to explain this problem is a transportation market with two products: cars and red busses, which each have a market share of 50%. Now a second bus is added, which has the color blue. The share of preference model would predict that the blue bus would take share equally from the car and red bus, so that the total bus share would become 67%. But it's more reasonable to expect that the blue bus would take share mostly from the red bus, and that the total bus share would remain close to 50%.

Although a model affected by IIA does not reflect realistic situations when there is no full independency across choice sets, the logit model can give a good estimation of the part worth utilities, if the condition is met that the alternatives are independent across choice sets (Louviere & Woodworth 1983). Moreover, some degree of IIA is proven useful in market simulations, because human decisions are not always completely rational. Also, there are several market simulation methods that help deal with IIA.

Although the levels used in this analysis are thought to be independent, no previous research has been performed on this topic and therefore no proof of level independence exists. Even if a model with correction for product similarity is used, it is not known what levels are dependent. Therefore, preferably a model is used for the analysis that is immune to IIA.

3.4.6.4 MARKET SIMULATOR MODELS

The software offers 5 different models based on an aggregate logit model that can be used as a market simulator tool:

- First Choice
- Share of Preference
- Share of Preference with Correction for Similarity
- Purchase Likelihood
- Randomized First Choice

The *first choice* model assumes that respondents choose the product with the highest overall utility, and is immune to IIA difficulties. However, this model requires individual-level utilities, and is therefore not suited to use in this study.

The *share of preference* model uses exponentiated product utilities, and the shares are normalized to sum to 100%. A weakness of this model however, is that it is subject to IIA. Especially with CBC under aggregate logit, the IIA problem is intensified.

The *purchase likelihood* model estimates the stated purchase likelihood for specified products independently on a scale from 0 to 100. Before applying this model, the utilities have to be rescaled by means of calibration concepts. Purchase Likelihood model are only as accurate as respondents' ability to predict their own purchase likelihoods for conjoint profiles. Experience has shown that respondents on average exaggerate their own purchase likelihood.

The *randomized first choice* method combines elements of the first choice and share of preference models. The randomized first choice model adds unique random error to the part worth utilities and computes shares of choice in the same manner as the first choice method. Each respondent is then sampled many times to stabilize the share estimates. This method can be made immune to IIA.

From these definitions, the randomized first choice method seems to be the model that is best used to analyze the data of this conjoint analysis, because it is a stable method to calculate utilities and can be made immune to IIA.

3.4.7 STEP 7 – POPULATION CHARACTERISTICS

The last step is to determine how the calculated individual preferences comply with the population of targeted users. It has to be identified whether the preferences are homogeneous or whether there are subpopulations with differing preferences. To be able to identify these subpopulations, respondents are asked several questions related to bladder problems and their thoughts on surgery. Calculations on subpopulations can be found in table 4 on page 35.

4. RESULTS

4.1 SURVEY COMPLETION

The time needed to complete the survey was about 40 minutes. Of the 90 persons asked to participate, 10% refused participation. 19 persons took the survey home, and 8 surveys (42.1%) were returned by mail. Of all filled-out surveys, 2 (2.9%) were inconsistent and 2 (2.9%) incomplete. These surveys were not used for analysis of the data. Characteristics of the sample used for data analysis are shown in table 1 and 2.

Table 1. *Sample Characteristics, N=66*

Characteristic		
Gender	*Male*	89.4%
	Female	10.6%
Age		50.6 ± 1.9
Race	*White*	66.7%
	Black/African American	27.3%
	Hispanic/Latino	3.0%
	Other	3.0%
Marital status	*Divorced/seperated*	31.8%
	Never married	28.8%
	Married	28.8%
	Widow	7.6%
	Other	3.0%
Educational level	*Less than high school*	6.0%
	High school/GED	34.8%
	Some college	31.8%
	Associates/Bachelor degree	18.2%
	Graduate degree	9.1%
Employment status	*Employed*	16.7%
	Unemployed	42.4%
	Retired	36.4%
	Other	4.5%
Injury	*Incomplete paraplegia*	19.7%
	Complete paraplegia	22.7%
	Incomplete tetraplegia	43.9%
	Complete tetraplegia	13.6%
Years since injury		14.0 ± 1.7
Age at injury		36.6 ± 1.8

Table 2. *Sample characteristics related to bladder neural prostheses, N=66*

Characteristic		
Dominance	*Not dominant*	80.3%
	Dominant – no neural prosthesis	19.7%
Impact bladder problems on QoL	*Great deal*	37.9%
	Some	42.4%
	None	12.2%
	No bladder problems	7.6%
Knowledge bladder NP	*Previous knowledge*	33.3%
	No previous knowledge	66.7%
Bladder management	*Self-intermittent catheterization*	22.7%
	Indwelling catheter	19.7%
	Suprapubic catheter	18.2%
	Condom	13.6%
	Other	25.7%

4.2 AVERAGE IMPORTANCE ATTRIBUTES

Using the data of the conjoint analysis, the relative importance of each individual attribute can be determined, and described in the following equation:

$P_{NP} = a_1 Invasiveness + a_2 Effect\ continence + a_3 Effect\ voiding + a_4 Side\ effects + a_5 User\ friendliness + a_6 Costs$

In table 3 the relative importances of each individual attribute are shown for three different groups: all respondents, not-dominant respondents, and dominant respondents. The importances indicated that the order of importance of the characteristics was different for the dominant and not-dominant respondents. Since this study focuses on persons that would like to have a neural prosthesis, all other analyses are done for the not-dominant respondents. For this group of respondents, the equation would be:

$P_{NP} = 0.10*Invasiveness + 0.25*Effect\ continence + 0.20*Effect\ voiding + 0.32*Side\ effects + 0.08*User\ friendliness + 0.05*Costs$

As can be seen in table 3, only the attribute "costs" did not have a statistically significant influence on the choice for a specific design of neural prosthesis for the persons that would like to have a neural prosthesis.

Table 3. *Relative importance attributes with level of significance for all respondents, the persons that would like to have a neural prosthesis (not dominant), and the persons that did not want to have a neural prosthesis (dominant)*

	All respondents (N=66)	Not dominant (N=53)	Dominant (N=13)
Invasiveness	0.13†	0.10†	0.30†
Effect on Continence	0.23†	0.25†	0.08§
Effect on Voiding	0.18†	0.20†	0.07§
Side Effects	0.33†	0.32†	0.33†
User Friendliness	0.08§	0.08*	0.05§
Costs	0.04§	0.05§	0.15§

* $p \leq 0.05$, † $p < 0.01$, § $p > 0.05$

4.3 RELATIVE PREFERENCE LEVELS

To calculate the relative preference for every individual level of all attributes, the levels were plotted on a scale from 0 to 1. The level with the most positive part worth utility (no side effects) was set at 1, and the level with the most negative part worth utility (side effects due to rhizotomy) was set at 0. Then the part worth utilities of all other levels were divided by the difference between these two values. Because of time limitations, statistical tests for significance between levels could not be performed. Graphs of the relative preference for each level are shown in figure 6. These graphs give information about the relative importance of every attribute, as well as the preference for each level. The steeper the slope of the graph, the higher the relative importance of that attribute, and the higher the value of a level, the more it is preferred.

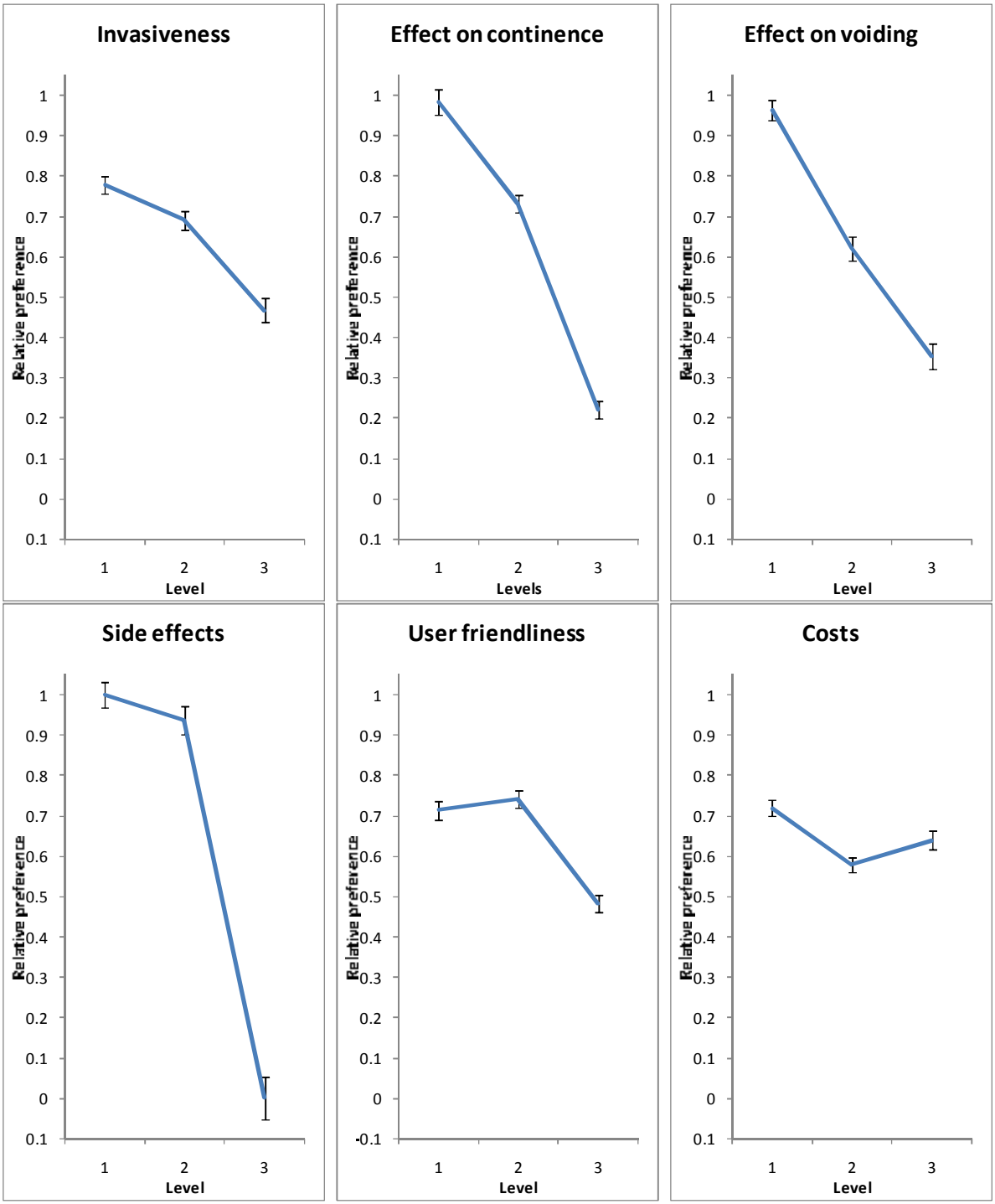

Figure 6. *Relative preference for each level of all attributes with standard error. Graphs based on 53 subjects. Level 1 is the most preferable level, level 3 the least preferable level (see figure 4). The larger the absolute difference between coefficients for the highest and lowest level, the more important the attribute. The higher the value of a level, the higher the relative preference for that particular level.*

Based on the graphs in figure 6, it seemed that side effects had a major impact on the decision process, and the effect on continence seemed to be the second most important attribute. The results will now be discussed for each attribute:

Invasiveness: People prefered not to have sacral root access, but the difference in impact between subcutaneous and pudendal nerve stimulation is less pronounced.

Effect on continence and effect on voiding: There was a linear relation in the importance for both "effect on continence" and "effect on voiding", and the difference between the highest and lowest level of the attribute "effect on continence" was larger. Also, the most positive level of "effect on continence" and "effect on voiding" did not indicate a difference with the intermediate level of "side effects".

Side effects: The attribute "side effects" had the largest importance of all attributes. However, respondents did not seem to distinguish between the levels "no side effects" and "occasional discomfort".

User Friendliness: The impact of this attribute mainly was the result of the impact of having to use an external device to recharge the neural prosthesis. There was no distinction between self-recharge and battery change every 5 years.

Costs: For this attribute, the intermediate level of $150 was the least preferred. But in general it seemed that respondents did not make relevant distinctions between the levels of the costs.

4.4 POSSIBLE SUBGROUPS

Table 4 gives an overview of the relative importance of all attributes for possible subgroups. The differences for every subgroup were:

Gender: For females, the user friendliness and costs were more important than for males.

Injury: For persons with incomplete paraplegia, the effect on voiding was more important than the effect on continence. For persons with complete tetraplegia, the effect on continence was the most important attribute. For persons with incomplete tetraplegia, side effects had a major impact on their decision for a neural prosthesis, whereas the invasiveness hardly had any impact.

Time since injury: There did not seem to be any relevant differences between the subgroups

Bladder management: For persons that use an indwelling catheter, the effect on continence was more important than the side effects. For the persons who use self-intermittent catheterization, a suprapubic catheter or a condom, the side effects generally seemed to have a larger impact than for persons that use an indwelling catheter or another bladder management method.

Impact bladder function on QoL: For the persons who stated that their bladder problems had a large influence on their QoL, the effect on continence was the most important attribute, while for the other subgroups, side effects were the most important.

Knowledge of bladder neural prostheses: There were not any relevant differences between the subgroups.

Experience surgery: The more negative the experience with surgery, the more important the attributes "effect on continence" and "invasiveness" became, whereas the side effects became less important. For the persons that had a negative experience with surgery, the effect on continence was more important than the side effects.

Bladder surgery: Persons that had experience with bladder surgery found the effect on voiding more important than persons that had not had any bladder surgery.

Table 4. *Overview of the relative importances of all attributes for possible subgroups* N=53*

Subgroup		Invasiveness	Effect on continence	Effect on voiding	Side effects	User friendliness	Costs
Gender	*Male*	0.10	0.25	0.21	0.32	0.08	0.04
	Female	0.11	0.19	0.14	0.32	0.14	0.10
Injury	*Complete parapiegia*	0.09	0.25	0.20	0.33	0.08	0.05
	Incomplete paraplegia	0.09	0.17	0.23	0.33	0.15	0.04
	Complete tetrapiegia	0.11	0.30	0.16	0.29	0.08	0.06
	Incomplete tetraplegia	0.02	0.23	0.22	0.41	0.06	0.06
Time since injury	*0-2 years*	0.12	0.23	0.17	0.33	0.08	0.06
	3-19 years	0.09	0.23	0.21	0.34	0.09	0.04
	20 and over	0.11	0.29	0.20	0.28	0.09	0.03
Bladder management	*Self intermittent*	0.09	0.23	0.16	0.36	0.10	0.06
	Indwelling catheter	0.15	0.29	0.19	0.26	0.08	0.04
	Suprapubic	0.06	0.20	0.21	0.41	0.09	0.03
	Condom	0.07	0.24	0.22	0.32	0.09	0.06
	Other	0.14	0.28	0.22	0.25	0.07	0.05
Impact QoL	*Great deal*	0.10	0.29	0.22	0.27	0.07	0.03
	Some	0.10	0.22	0.16	0.36	0.09	0.07
	None	0.08	0.22	0.20	0.35	0.12	0.04
	No bladder problems	0.13	0.18	0.26	0.29	0.10	0.05
Knowledge NP	*Previous knowledge*	0.14	0.25	0.17	0.32	0.08	0.04
	No knowledge	0.08	0.24	0.21	0.32	0.09	0.05
Experience surgery	*Positive*	0.08	0.23	0.21	0.35	0.09	0.03
	Neutral	0.11	0.29	0.15	0.31	0.09	0.05
	Negative	0.14	0.32	0.19	0.28	0.03	0.04
Bladder surgery	*No bladder surgery*	0.10	0.25	0.18	0.33	0.08	0.04
	Previous bladder surgery	0.09	0.25	0.25	0.29	0.10	0.02

**Because of the small sample size, no statistical analysis was performed on the data.*

4.5 WILLINGNESS TO PAY

Since the attribute "costs" does not have a significant effect on the choice for a neural prosthesis, the willingness to pay could not be determined.

4.6 DIRECT COMPARISON

The outcome of the direct comparison was based on the choices respondents made for the fixed scenarios. Here, three existing designs for neural prostheses were compared in three choice sets, resulting in a ranking of those three designs. Of the 53 respondents 5.6% did not have a logical order in their ranking.

As shown in table 5 and 6, the rhizotomy-free Vocare was the most preferred option for a neural prosthesis to restore bladder function, followed by the pudendal nerve based afferent stimulation. The currently available Brindley device was chosen last in 56.6% of all cases.

Table 5 *Outcome direct comparison, N=53*

Order	Percentage
SRS alternative>pudendal>SRS rhizotomy	39.6
pudendal>SRS alternative>SRS rhizotomy	17.0
SRS rhizotomy>SRS alternative>pudendal	17.0
SRS alternative>SRS rhizotomy>pudendal	9.3
pudendal>SRS rhizotomy>SRS alternative	5.7
SRS rhizotomy>pudendal>SRS alternative	5.7
No logical order	5.7

Table 6. *Summary direct comparison*. N=53*

	Rhizotomy-free Vocare	*Pudendal nerve based afferent stimulation*	*Brindley (Vocare)*
First choice	*48.9%*	*22.7%*	*22.7%*
Second choice	*34.0%*	*45.3%*	*15.0%*
Third choice	*11.4%*	*26.3%*	*56.6%*

**Choices add up to 94.3%, because 5.7% was inconsistent (see table 5)*

4.7 OUTCOME DIRECT COMPARISON & VALIDITY

The overall outcome of the direct comparison for all respondents equaled the outcome of the conjoint analysis. According to both methods, the rhizotomy-free Vocare would be the most preferred option, followed by the pudendal nerve based afferent stimulation.

Comparing of the outcome of the CBC with the outcome of the direct comparison on an individual level revealed that these outcomes matched in 41.5% of the cases. As mentioned before, 5.7% of the cases did not have a logical order in the direct comparison, and in another 5.7% of the cases validity could not be determined. Of the remaining 47.1% of the cases in which the outcome of the direct comparison did not match the outcome of the CBC, the most important attribute matched in 48.0% of cases. So looking only at the most important attribute, the outcomes of the direct comparison and CBC matched in 64.1% of cases.

5. DISCUSSION

5.1 OVERVIEW

A number of studies have revealed that restoration of bladder function would be highly appreciated by persons with SCI, but until now there have not been studies examining user preferences for bladder neural prostheses. In this study, we have investigated the relative importances of a number of attributes of bladder neural prostheses to the SCI population, being invasiveness, effect on continence, effect on voiding, side effects, user friendliness and costs. The focus of this study was on persons that want to have neural prosthesis, since that group determines clinical successfulness.

5.2 SAMPLE VS. NATIONAL SCI POPULATION

According to the most recent figures of the National Spinal Cord Injury Statistical Center (2008), the sample used for this study matched the total population of persons with SCI in the sense that the largest group of respondents had incomplete tetraplegia, followed by a group of persons with complete paraplegia. Also, the largest ethnic group in both the sample and the national population is Caucasian, followed by African Americans and Hispanics, and the average age at injury of this sample was similar to that of the national population (36.6±1.6 vs. 39.5 years).

Characteristics of the sample that did not match the national SCI population were the percentage of women in the sample, which was lower than in the total population (10.6% vs. 22.2%). Since one study site was a Veterans Administration Medical Center, it was not unexpected that the study sample would include a higher percentage of males compared to the national average.

5.3 AVERAGE IMPORTANCE ATTRIBUTES

The results of the average importances of all attributes revealed that the attribute "side effects" has the highest relative importance, followed by "effect on continence" and "effect on voiding".

Of all attributes, the attribute "costs" was the only attribute that did not have a statistically significant impact on the choice for a neural prosthesis design. An explanation could be that the levels for costs were not set correctly. To be able to set the levels for the attribute "costs", a small sample of persons with SCI were informed about the option to restore bladder function with a neural prosthesis, and then asked how much they would be willing to pay for such a device. That small sample might have been biased, or people might not have had enough information about the technique to completely realize what the benefits could be, thereby underestimating the willingness to pay.

5.4 RELATIVE PREFERENCE LEVELS

The fact that all attributes had a negative correlation implies that the assumed set up of the levels from most positive to most negative was as experienced by respondents.

5.4.1 INVASIVENESS

The attribute "invasiveness" had a low relative importance. However, there was a higher preference for the most positive level of invasiveness than the intermediate level of the characteristic "effect on continence" and "effect on voiding". This indicates that respondents preferred a device with low invasiveness over a device that does not give them complete bladder function.

5.4.2 EFFECT ON CONTINENCE AND EFFECT ON VOIDING

For the attributes "effect on continence" and "effect on voiding", the effect on continence had a larger relative importance than the effect on voiding. This implies that persons with SCI have more problems with incontinence, than with using a catheter. That the difference between "no effect on continence" and "improved continence" was larger than that between "improved continence" and "complete continence" implies that respondents highly appreciate even a minor positive effect on continence. The fact that there did not seem to be a difference between "complete continence" or "complete voiding" and "minor side effects", reveals that respondents are willing to put up with minor side effects, as long as the effect on bladder function is profound.

5.4.3 SIDE EFFECTS

The graphs comparing the relative preferences for all levels of each attribute clearly showed that the attribute "side effects" had the largest difference between the most positive and most negative level, and therefore the highest relative importance. This effect seemed to be caused mainly by the side effects due to rhizotomy, while there was no relevant difference between the preferences for the levels "no side effects" or "occasional discomfort". This reveals that for most respondents rhizotomy is out of the question, but they are willing to put up with minor side effects. The large negative impact of the side effects due to rhizotomy implies that these side effects have a large negative impact on the clinical implementation of the Vocare device.

5.4.4 USER FRIENDLINESS

The relative importance of the attribute "user friendliness" was low, and the most positive and intermediate level were not different, which implies that respondents do not mind if they have to recharge the neural prosthesis themselves. However, the preference for the remaining level was significantly lower, indicating that respondents rather not use an external device to operate the neural prosthesis.

5.4.5 COSTS

For the costs, the intermediate level of $150 seemed to be less beneficial than the level of $400. This is probably caused by an underestimation of the willingness to pay when the levels were set, as mentioned before. This could cause this attribute to have such a low relative importance that there is no significant difference between the levels. Because there is no difference in the levels for costs, the willingness to pay could not be determined.

5.5 DIRECT COMPARISON

For 56.6% of the respondents, sacral root stimulation with rhizotomy was the least preferred choice. Looking at the first and second choice, 48.9% of the respondents preferred the sacral root stimulation with an alternative for rhizotomy over pudendal nerve stimulation. So although rhizotomy was out of the question due to the side effects, persons focused mainly on the effects on bladder function, and therefore choose to have a more invasive treatment with better effects. This outcome was in accordance with the outcome of the conjoint data, which also revealed that "side effects" was the most important attribute, followed by "effect on continence" and "effect on voiding".

5.6 SUBGROUPS

Although the sample size used did not allow for statistical analysis on subgroups, some trends were found in the data.

5.6.1 GENDER

For females the user friendliness and costs seemed to be more important than for males. However, since there were only six females that participated in the survey, the sample for females might be biased. Another remarkable outcome of the comparison of males and females is that, in contrast with what might be expected, the side effects are equally important for both groups. This implies that rhizotomy does not only matter to males, but also to females.

5.6.2 INJURY

For persons with incomplete paraplegia the effect on voiding was more important than the effect on continence. For persons with complete tetraplegia the effect on continence was the most important attribute. For persons with incomplete tetraplegia the side effects had a major impact on their decision for a neural prosthesis, whereas the invasiveness hardly had any impact. Although there did not seem to be any relevant differences between persons with paraplegia and tetraplegia, there seemed to be a trend that the effect on voiding was more important to persons with an incomplete lesion than to persons with a complete lesion.

5.6.3 TIME SINCE INJURY

Whereas it could be expected that persons who just recently got their injury could have other preferences than persons that had their injury for a longer period of time, the outcome of this survey did not reveal distinctive differences between these two groups. However, there seemed to be an effect of the time since injury on whether persons would like to have a neural prosthesis or not (see discussion about dominance, p41).

5.6.4 BLADDER MANAGEMENT

For persons who use an indwelling catheter, the effect on continence was more important than the side effects. This could indicate that this group of persons with SCI is more troubled with their current bladder management method than the other subgroups investigated, and are therefore more willing to put up with side effects if their bladder function is improved. In general it seemed that the weight of possible side effects increases with the amount of time persons have to spend on their bladder management.

5.6.5 IMPACT BLADDER FUNCTION ON QOL

For the persons who stated that their bladder problems have a large influence on their QoL, the effect on continence was the most important attribute, while for the other subgroups the side effects were the most important. This indicates that persons that are more troubled with their bladder dysfunction are more willing to undergo a procedure with a chance for side effects to improve their bladder function than persons that are less troubled with their bladder function. Persons that did not have bladder problems ranked the effect on voiding as the second most important attribute, and thought that invasiveness was slightly more important than other subgroups indicated. However, assuming that "effect on continence" and "effect on voiding" both represent the effect on bladder function, the rating of persons that do not have bladder problems is similar to that of persons that have bladder problems.

5.6.6 KNOWLEDGE OF BLADDER NEURAL PROSTHESES

Knowledge or previous experience with bladder neural prostheses did not seem to influence the ranking of relative importances of the attributes. However, the questionnaire did not establish the level of knowledge persons had of bladder neural prostheses. In most cases persons stated that they "heard about those devices" or "knew someone who had one". Only 2 persons actually had the Vocare device implanted. At least it has become clear that the majority of respondents (66.7%) had never heard of a neural prosthesis to restore bladder function. Educating persons about bladder neural prostheses could make them more aware of the advantages, thereby lowering the current importance of the attribute "side effects".

5.6.7 EXPERIENCE SURGERY

The more negative the experience with surgery, the more important the attributes "effect on continence" and "invasiveness" become, whereas the side effects become less important. A possible explanation could be that persons who had a negative experience with previous surgical procedures are more afraid for another negative experience with a more invasive procedure. Additionally, the procedure has to have a major positive effect on their bladder function, before they would even consider that procedure. This can explain why, for persons with a negative experience with surgery, the effect on continence is more important than the side effects.

5.6.8 BLADDER SURGERY

Persons that had experience with bladder surgery found the effect on voiding more important than persons that did not have any bladder surgery. There are a number of possible explanations for this difference. For instance, persons that had previous bladder surgery might have more trouble now with voiding than persons that did not have bladder surgery. Or they had their previous bladder surgery to improve voiding and experienced a major gain in their QoL.

Looking at the results of comparing possible subgroups, it seems like there were quite some subgroups with differing preferences. However, for most subgroups the most important attribute was still "side effects", and even for the subgroups where side effects was the second most important attribute, it was still close to the most important attribute. These data suggest that it is not necessary to develop different neural prostheses for different subgroups, since all data imply that side effects and the effect on bladder function are the most important attributes. However, a majority of the respondents had never heard of the option to restore bladder function with a neural prosthesis, and educating persons with SCI about bladder neural prostheses and the difference those devices can make, could have a significant impact on their preferences, and would probably lower the impact of side effects because people can make a well-balanced choice.

5.7 DOMINANCE

Of all respondents 13 (19.7%) did not want to have a bladder neural prosthesis at all. The reason why they did not want to have a neural prosthesis, were diverse and ranging from "afraid of surgery" to "rather hoping that function will come back by itself". Also, the group of respondents that did not want to have a neural prosthesis had a relatively high percentage of persons that did not have bladder problems, compared to the group of persons that wanted to have a neural prosthesis (15.4% vs. 5.7%). These persons might underestimate the impact of bladder problems on the QoL.

Another characteristic was that of the group of persons that did not want to have a neural prosthesis, is that a relatively large group had their SCI for 1 year or less, or for more than 15 years (84.6% vs 52.8%). The persons that were injured only recently might hope that function will come back, whereas the persons that had their injury for more than 15 years are used to their daily bladder routine.

Other differences between the sample of not-dominant and dominant persons, was that the percentage of persons with paraplegia was larger in the dominant group (61.5% vs. 37.8%). Also, the percentage of persons that stated their current bladder function had a major impact on their QoL was smaller in the dominant group (23.1% vs. 41.5%). However, from the small sample of persons with a dominant preference, there did not seem to be a relation between these two characteristics.

Persons with a dominant preference seemed not only to have a strong preference not to have a neural prosthesis, but also seemed to focus more on one specific attribute while filling out the CBC. This could be the reason that the order of importance is different for dominant persons than for persons that would like to have a neural prosthesis, since the sample size for dominant persons consists of only 13 persons and can therefore be biased.

5.8 INTERACTION & CONFOUNDING FACTORS

The main purpose of this study was to investigate main effects of the determined attributes on the decision making process. A larger sample size is necessary to determine interaction effects for the different attributes or other confounding factors. For instance, it can be argued that there could be an interaction between "effect on continence" and "effect on voiding", since both attributes resemble aspects of bladder function. Other confounding factors could be interactions between subgroups. For example, persons that were familiar with the concept bladder neural prosthesis, might currently also have more advanced bladder management methods. Also, bladder management method and impact of bladder function on QoL might be related, as well as gender and bladder management.

5.9 VALIDITY

In three fixed choice tasks, the respondents had to choose between existing designs of neural prostheses. The choices made in the choice task indirectly resulted in a ranking of the existing designs. Then this ranking was compared to the outcome of the random choice tasks (CBC data) which is a method to determine the validity of the survey.

The average outcome of the direct comparison and the CBC data both revealed that the side effects due to rhizotomy have the largest relative importance, followed by the effect. This finding implies that the survey is valid. However, looking at the individual level, only 41.5% of the outcome of the direct comparison matches the CBC data of that individual. This can be explained by the fact that the three fixed scenarios for the direct comparison only occurred once throughout the survey, whereas the outcome of the CBC data is based upon 14 scenarios. So the CBC data are more solid, whereas one inconsistent choice in the fixed scenarios will have an immediate effect on the outcome of the direct comparison.

The low percentage of outcome matches for the direct comparison and CBC data is mainly caused by the low reliability of the direct comparison, instead of indicating the survey is not valid. For future use of a direct comparison, it is therefore recommended to repeat the choice sets in order to make the outcome more reliable. However, it can be questioned whether the extra reliability is worth the addition of extra choice sets, since participating in a CBC already is a time consuming activity for respondents.

5.10 CONCLUSION

This study revealed that persons with SCI would preferably have a bladder neural prosthesis with subcutaneously placed electrodes that gives them complete bladder function, with no side effects and that can be operated by pushing a button and they do not have to recharge themselves. Clearly, developing a device with all these characteristics would be very challenging. But this survey also revealed that persons with SCI rate the importance of the effect on bladder function higher than the invasiveness of the procedure or the chance on side effects like occasional discomfort. So a prosthesis design that uses sacral root stimulation without cutting any nerves would be accepted by users, as long as the positive effect on bladder function is profound. Therefore, a design that completely restores bladder function, combined with an alternative for rhizotomy, would be a promising design that would be accepted by persons with SCI when clinically available.

In short, this study indicated that the side effects of rhizotomy limit the clinical implementation of Brindley's Vocare device, and that a design with the same effect on bladder function, but without rhizotomy would be the most likely to be accepted by users. Other characteristics like invasiveness and user friendliness are inferior to a combination of completely restored bladder function without rhizotomy-related side effects.

5.11 STUDY LIMITATIONS

This study was the first to specifically investigate the user preferences for neural prostheses to restore bladder function. The investigative nature of this study combined with time limits, resulted in obtaining the absolute minimum of subjects. Moreover, as discussed before, the sample did not match the national SCI population's percentage of women. These characteristics of the study limit the applicability of the results, although the study did give a clear impression of user preferences. Studies with larger sample sizes would provide more generalizable data.

A confounding factor in this study may have been the way the data were presented to the respondents. The order by which the attributes were presented was the same for every scenario. This made it more time-efficient for respondents to fill out the survey, but order effects might have occurred, thereby biasing the outcome (Chrzan 1994). Another factor was that most surveys were performed face to face, where the investigator read all options out loud, thereby making sure the respondent would take all attributes into consideration. Some respondents, however, self-administered the survey. This last group of respondents may not have read the levels of all attributes, but instead focused on one or two attributes. Also, the choice for a paper and pencil survey has limited the information that could be obtained with this method, since a computer mode survey would have allowed an unlimited number of versions and thereby an unlimited number of scenarios. However, the fact that the survey was performed at multiple sites and the option of respondents to take the survey home, made a paper and pencil version necessary.

To exactly determine the importance of characteristics for subgroups or to investigate interactions, a larger sample size is needed. However, with the sample used in this study the main effects for different attributes could be determined, and gave an impression of possible subgroups and interactions. Also, a more thorough investigation would be necessary to determine the willingness to pay before the levels for the attribute "costs" are set up.

5.12 CHOICE BASED CONJOINT ANALYSIS

After careful consideration, the choice has been made to use CBC for this study because this method seemed to be the most suitable to examine user preferences for new products. Looking back at the results, the choice to use CBC has met the expectations. Although rather time consuming, this method has revealed differences in importance for different attributes, including the more subtle differences between levels. For instance the finding that respondents are willing to put up with minor side effects, as long as there is a profound effect on continence, probably would not have been revealed when an ordinal 10-points scale would have been used. One of the factors causing this difference is the fact that respondents have to take a full profile into consideration with a CBC, while using a 10-points scale to rate the levels of attributes does not require a respondent to take a full profile into consideration. Therefore, with a 10-points scale the trade-offs respondents make are not revealed.

5.13 RECOMMENDATIONS & FUTURE WORK

Future use of a choice based conjoint analysis should use a larger sample size to reveal all aspects that can be measured with a choice based conjoint analysis like interactions and subgroups, and more time will enable researchers to perform more statistical analyses. Moreover, more information can be obtained when a computerized version of the survey is performed, although this might be problematic when the survey is performed at multiple sites.

This survey indicates that designing a bladder neural prosthesis with a profound effect on bladder function, but without rhizotomy-related side effects, will have the largest chance of successful implementation. So researchers should focus on developing a neural prosthesis that functionally completely restores continence and voiding, without a necessity of rhizotomy. Although rhizotomy is out of the question for respondents, they are willing to put up with minor side effects or a high invasive procedure, as long as the effect on bladder function is profound. However, if complete continence and complete voiding cannot be achieved without rhizotomy, especially invasiveness becomes a factor of importance. If bladder function is only improved, then respondents would rather have a device design that requires a low-invasive procedure. So in that situation researchers should also focus on invasiveness.

Another important outcome of this study is that a majority of persons with SCI had never heard of neural prostheses to restore bladder function. Educating these persons can make them more aware of the benefits, thereby changing overall user preferences towards an increased willingness to accept for instance side effects or an invasive procedure.

As mentioned in the discussion, the levels for the attribute costs were set too low to provide a reliable indication of the willingness to pay. Future studies investigating the willingness to pay should investigate more extensively how much persons that belong to the population under investigation would be willing to pay, before setting the levels of the attribute costs. To do so, researchers have to make sure that persons asked to answer this question have enough information to make a reliable estimation, and that the persons are a representative sample of the total population.

This study also shows that choice based conjoint analysis can reveal main trends in user preferences for attributes, and more subtle ranking of levels, using a relatively small sample size. Similar surveys can be performed for all kinds of medical devices or applications, and can have an important contribution in devising an accepted and therefore clinically successful device, providing guidelines for researchers regarding acceptance towards design and function.

6. EPILOGUE

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6.2 SOME LAST WORDS

Although making all arrangements to perform this project in the US was quite stressful, especially with all the visa regulations, I am very satisfied how everything turned out. I got my visa less than two weeks before departure, but the whole process of filling out forms and the subsequent waiting has prepared me for the process of getting IRB approval for a project. But as soon as I got that approval, a large number of respondents was recruited in a short period of time, all thanks to the help of the people mentioned above. I could not have done it without them. Also, the supervision in Cleveland and from the Netherlands was great. And although the process of getting IRB approval has caused that I will graduate a month later than planned, it was a good experience that has prepared me for a future in the medical industry.

Also, I really enjoyed working at the NEC. The people there were friendly and helpful from the start, even though they did not know me at all. I liked the set up of the NEC too, where people of multiple labs are working in the same room. In this way, I got to know a lot of people, and had a good sense of what all the other labs were working on. And I think a lot of very good and important research is being done at the NEC.

During my time in the US, I was able to see quite a bit of the country. I really liked the bustling life in New York, fell in love with San Francisco, was impressed by the Grand Canyon and enjoyed the beauty of Yosemite. But the thing I enjoyed most overall, was getting to know the culture and the people in the US. Although a little too polite sometimes, I have experienced people in the US as being very friendly and helpful. If it only looks like you are lost, people will ask you whether you need help finding something. Also, people are very positive, and complete strangers will tell you they "like your glasses". The Dutch can learn a lot from this.

Performing an internship abroad was a great experience, and I encourage every student to do it if you have the chance. It might not be the most convenient route to follow; it takes some extra effort and persistence to get everything arranged, but it is definitely worth it. I had a great time, got to learn a lot on both a professional and social level, and made some friends for life.

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8. APPENDIX

APPENDIX 1 – SURVEY

Now that the study has been explained to you, I will show you an example so you know how the survey works. You will be given two descriptions for neural prostheses. I would like you to choose which of the two you would prefer. After you have made your choice, I will ask whether you would actually like to be treated with the choice you made or you would prefer no treatment at all.

Lets go through the example:

If these were your only treatment options, which would you choose?
Choose by checking on of the options below:

Option A	Option B
Electrodes implanted through surgery in lower part of your spinal cord, about 1 week hospital admission	Electrodes placed under skin, no hospital admission
No effect on continence or number of accidents	Complete continence, no more accidents
No change in amount of urine you can void	Complete voiding, no catheterization needed
Side effects may include permanently lost sexual sensation, no reflex erections and no self-induced defecation	No side effects
External device needed to activate neural prosthesis, has to be recharged every day/week [1]	No external device needed to activate neural prosthesis, battery has to be changed every 5 years with minor surgical intervention
$ 400 [2]	No out of pocket costs
☐	☐

Suppose you now have the option of no treatment at all, what would you prefer now?

☐ I would still prefer the treatment chosen above
☐ I would prefer no treatment

1. An external device is about the size of a mobile phone, and you have to aim it at an implanted receiver to activate the neural prosthesis. Recharging the external device also works like recharging a mobile phone. If no external device is needed to activate the neural prosthesis, this means you simply have to push a button that is connected to the prosthesis to activate it. Recharging that neural prosthesis means that you have to connect the implanted device to the electricity grid.
2. The costs involve the amount you have to pay to get the procedure done, corrected for reimbursements of insurance companies. Note that the standard procedure is fully reimbursed by health insurance companies. This procedure requires surgery, and therefore hospital admission, and improves, but not fully recovers bladder function.

To get a general idea of your situation, we would like to start with asking you the following questions: *(please encircle the answer that applies to you)*

How much of an impact does your current bladder function have on your quality of life?

1. A great deal
2. Some
3. A little bit
4. Not at all
5. I don't have bladder problems

Were you aware of the possibility to treat bladder dysfunction with neural prostheses previous to participation in this study?

Yes / no

1. If these were your only treatment options, which would you choose?
Choose by checking on of the options below:

Option A	Option B
Electrodes implanted through surgery in lower part of your spinal cord, about 1 week hospital admission	Electrodes placed under skin, no hospital admission
Improved continence, but still occasional accidents	No effect on continence or number of accidents
No change in amount of urine you can void	Complete voiding, no catheterization needed
Side effects may include occasional discomfort	Side effects may include permanently lost sexual sensation, no reflex erections and no self-induced defecation
External device needed to activate neural prosthesis, has to be recharged every day/week	No external device needed to activate neural prosthesis, device has to be recharged by yourself every day/week
No out of pocket costs	$400
☐	☐

Suppose you now have the option of no treatment at all, what would you prefer now?

☐ I would still prefer the treatment chosen above
☐ I would prefer no treatment

2. If these were your only treatment options, which would you choose?
Choose by checking on of the options below:

Option A	Option B
Electrodes implanted through surgery in lower part of your spinal cord, about 1 week hospital admission	Electrodes implanted in surgery via buttocks, 1-3 days hospital admission
No effect on continence or number of accidents	Complete continence, no more accidents
Complete voiding, no catheterization needed	Improved voiding, but catheter still needs to be used sometimes
Side effects may include occasional discomfort	No side effects
External device needed to activate neural prosthesis, has to be recharged every day/week	No external device needed to activate neural prosthesis, battery has to be changed every 5 years with minor surgical intervention
$400	$150
☐	☐

Suppose you now have the option of no treatment at all, what would you prefer now?

☐ I would still prefer the treatment chosen above
☐ I would prefer no treatment

3. If these were your only treatment options, which would you choose?
Choose by checking on of the options below:

Option A	Option B
Electrodes placed under skin, no hospital admission	Electrodes implanted in surgery via buttocks, 1-3 days hospital admission
Complete continence, no more accidents	Improved continence, but still occasional accidents
No change in amount of urine you can void	Improved voiding, but catheter still needs to be used sometimes
No side effects	Side effects may include permanently lost sexual sensation, no reflex erections and no self-induced defecation
No external device needed to activate neural prosthesis, battery has to be changed every 5 years with minor surgical intervention	No external device needed to activate neural prosthesis, device has to be recharged by yourself every day/week
$150	No out of pocket costs
☐	☐

Suppose you now have the option of no treatment at all, what would you prefer now?

☐ I would still prefer the treatment chosen above
☐ I would prefer no treatment

4. If these were your only treatment options, which would you choose?
Choose by checking on of the options below:

Option A	Option B
Electrodes implanted through surgery in lower part of your spinal cord, about 1 week hospital admission	Electrodes placed under skin, no hospital admission
Complete continence, no more accidents	Improved continence, but still occasional accidents
Complete voiding, no catheterization needed	Improved voiding, but catheter still needs to be used sometimes
Side effects may include permanently lost sexual sensation, no reflex erections and no self-induced defecation	No side effects
No external device needed to activate neural prosthesis, battery has to be changed every 5 years with minor surgical intervention	External device needed to activate neural prosthesis, has to be recharged every day/week
No out of pocket costs	$400
☐	☐

Suppose you now have the option of no treatment at all, what would you prefer now?

☐ I would still prefer the treatment chosen above
☐ I would prefer no treatment

5. If these were your only treatment options, which would you choose?
Choose by checking on of the options below:

Option A	Option B
Electrodes implanted through surgery in lower part of your spinal cord, about 1 week hospital admission	Electrodes implanted through surgery in lower part of your spinal cord, about 1 week hospital admission
Improved continence, but still occasional accidents	Complete continence, no more accidents
Complete voiding, no catheterization needed	Complete voiding, no catheterization needed
Side effects may include occasional discomfort	Side effects may include permanently lost sexual sensation, no reflex erections and no self-induced defecation
No external device needed to activate neural prosthesis, battery has to be changed every 5 years with minor surgical intervention	No external device needed to activate neural prosthesis, battery has to be changed every 5 years with minor surgical intervention
No out of pocket costs	No out of pocket costs
☐	☐

Suppose you now have the option of no treatment at all, what would you prefer now?
- ☐ I would still prefer the treatment chosen above
- ☐ I would prefer no treatment

6. If these were your only treatment options, which would you choose?
Choose by checking on of the options below:

Option A	Option B
Electrodes implanted through surgery in lower part of your spinal cord, about 1 week hospital admission	Electrodes implanted in surgery via buttocks, 1-3 days hospital admission
Improved continence, but still occasional accidents	No effect on continence or number of accidents
No change in amount of urine you can void	Improved voiding, but catheter still needs to be used sometimes
Side effects may include permanently lost sexual sensation, no reflex erections and no self-induced defecation	Side effects may include occasional discomfort
No external device needed to activate neural prosthesis, battery has to be changed every 5 years with minor surgical intervention	No external device needed to activate neural prosthesis, device has to be recharged by yourself every day/week
$400	$150
☐	☐

Suppose you now have the option of no treatment at all, what would you prefer now?

☐ I would still prefer the treatment chosen above
☐ I would prefer no treatment

7. If these were your only treatment options, which would you choose?
Choose by checking on of the options below:

Option A	Option B
Electrodes implanted in surgery via buttocks, 1-3 days hospital admission	Electrodes placed under skin, no hospital admission
No effect on continence or number of accidents	Complete continence, no more accidents
Complete voiding, no catheterization needed	No change in amount of urine you can void
No side effects	Side effects may include occasional discomfort
External device needed to activate neural prosthesis, has to be recharged every day/week	No external device needed to activate neural prosthesis, device has to be recharged by yourself every day/week
No out of pocket costs	$150
☐	☐

Suppose you now have the option of no treatment at all, what would you prefer now?

☐ I would still prefer the treatment chosen above
☐ I would prefer no treatment

8. If these were your only treatment options, which would you choose?
Choose by checking on of the options below:

Option A	Option B
Electrodes implanted in surgery via buttocks, 1-3 days hospital admission	Electrodes implanted through surgery in lower part of your spinal cord, about 1 week hospital admission
Complete continence, no more accidents	Improved continence, but still occasional accidents
No change in amount of urine you can void	Complete voiding, no catheterization needed
Side effects may include permanently lost sexual sensation, no reflex erections and no self-induced defecation	No side effects
External device needed to activate neural prosthesis, has to be recharged every day/week	No external device needed to activate neural prosthesis, device has to be recharged by yourself every day/week
$400	$150
☐	☐

Suppose you now have the option of no treatment at all, what would you prefer now?

☐ I would still prefer the treatment chosen above
☐ I would prefer no treatment

9. If these were your only treatment options, which would you choose?
Choose by checking on of the options below:

Option A	Option B
Electrodes are placed under skin, no hospital admission	Electrodes implanted in surgery via buttocks, 1-3 days hospital admission
No effect on continence or number of accidents	Improved continence, but still occasional accidents
Improved voiding, but catheter still needs to be used sometimes	Complete voiding, no catheterization needed
Side effects may include occasional discomfort	Side effects may include permanently lost sexual sensation, no reflex erections and no self-induced defecation
No external device needed to activate neural prosthesis, battery has to be changed every 5 years with minor surgical intervention	External device needed to activate neural prosthesis, has to be recharged every day/week
No out of pocket costs	$150
☐	☐

Suppose you now have the option of no treatment at all, what would you prefer now?

☐ I would still prefer the treatment chosen above
☐ I would prefer no treatment

10. If these were your only treatment options, which would you choose?
Choose by checking on of the options below:

Option A	Option B
Electrodes implanted in surgery via buttocks, 1-3 days hospital admission	Electrodes implanted through surgery in lower part of your spinal cord, about 1 week hospital admission
Improved continence, but still occasional accidents	Improved continence, but still occasional accidents
Improved voiding, but catheter still needs to be used sometimes	Complete voiding, no catheterization needed
Side effects may include occasional discomfort	Side effects may include occasional discomfort
No external device needed to activate neural prosthesis, battery has to be changed every 5 years with minor surgical intervention	No external device needed to activate neural prosthesis, battery has to be changed every 5 years with minor surgical intervention
No out of pocket costs	No out of pocket costs
☐	☐

Suppose you now have the option of no treatment at all, what would you prefer now?

☐ I would still prefer the treatment chosen above
☐ I would prefer no treatment

11. If these were your only treatment options, which would you choose?
Choose by checking on of the options below:

Option A	Option B
Electrodes placed under skin, no hospital admission	Electrodes implanted through surgery in lower part of your spinal cord, about 1 week hospital admission
Improved continence, but still occasional accidents	Complete continence, no more accidents
No change in amount of urine you can void	Improved voiding, but catheter still needs to be used sometimes
Side effects may include occasional discomfort	No side effects
No external device needed to activate neural prosthesis, battery has to be changed every 5 years with minor surgical intervention	No external device needed to activate neural prosthesis, device has to be recharged by yourself every day/week
No out of pocket costs	$400
☐	☐

Suppose you now have the option of no treatment at all, what would you prefer now?

☐ I would still prefer the treatment chosen above
☐ I would prefer no treatment

12. If these were your only treatment options, which would you choose?
Choose by checking on of the options below:

Option A	Option B
Electrodes implanted in surgery via buttocks, 1-3 days hospital admission	Electrodes implanted in surgery via buttocks, 1-3 days hospital admission
Complete continence, no more accidents	No effect on continence or number of accidents
Improved voiding, but catheter still needs to be used sometimes	No change in amount of urine you can void
Side effects may include occasional discomfort	Side effects may include occasional discomfort
No external device needed to activate neural prosthesis, device has to be recharged by yourself every day/week	No external device needed to activate neural prosthesis, device has to be recharged by yourself every day/week
No out of pocket costs	No out of pocket costs
☐	☐

Suppose you now have the option of no treatment at all, what would you prefer now?

☐ I would still prefer the treatment chosen above
☐ I would prefer no treatment

13. If these were your only treatment options, which would you choose?
Choose by checking on of the options below:

Option A	Option B
Electrodes implanted in surgery via buttocks, 1-3 days hospital admission	Electrodes implanted through surgery in lower part of your spinal cord, about 1 week hospital admission
Complete continence, no more accidents	No effect on continence or number of accidents
Complete voiding, no catheterization needed	Improved voiding, but catheter still needs to be used sometimes
Side effects may include occasional discomfort	Side effects may include permanently lost sexual sensation, no reflex erections and no self-induced defecation
No external device needed to activate neural prosthesis, battery has to be changed every 5 years with minor surgical intervention	External device needed to activate neural prosthesis and has to be recharged every day/week
$400	$150
☐	☐

Suppose you now have the option of no treatment at all, what would you prefer now?

☐ I would still prefer the treatment chosen above
☐ I would prefer no treatment

14. If these were your only treatment options, which would you choose?
Choose by checking on of the options below:

Option A	Option B
Electrodes placed under skin, no hospital admission	Electrodes implanted through surgery in lower part of your spinal cord, about 1 week hospital admission
No effect on continence or number of accidents	Complete continence, no more accidents
Complete voiding, no catheterization needed	No change in amount of urine you can void
No side effects	Side effects may include occasional discomfort
No external device needed to activate neural prosthesis, device has to be recharged by yourself every day/week	External device needed to activate neural prosthesis and has to be recharged every day/week
No out of pocket costs	$150
☐	☐

Suppose you now have the option of no treatment at all, what would you prefer now?

☐ I would still prefer the treatment chosen above
☐ I would prefer no treatment

15. If these were your only treatment options, which would you choose?
Choose by checking on of the options below:

Option A	Option B
Electrodes implanted through surgery in lower part of your spinal cord, about 1 week hospital admission	Electrodes implanted in surgery via buttocks, 1-3 days hospital admission
Complete continence, no more accidents	Improved continence, but still occasional accidents
Complete voiding, no catheterization needed	Improved voiding, but catheter still needs to be used sometimes
Side effects may include permanently lost sexual sensation, no reflex erections and no self-induced defecation	Side effects may include occasional discomfort
No external device needed to activate neural prosthesis, battery has to be changed every 5 years with minor surgical intervention	No external device needed to activate neural prosthesis, battery has to be changed every 5 years with minor surgical intervention
No out of pocket costs	No out of pocket costs
☐	☐

Suppose you now have the option of no treatment at all, what would you prefer now?

☐ I would still prefer the treatment chosen above
☐ I would prefer no treatment

16. If these were your only treatment options, which would you choose?
Choose by checking on of the options below:

Option A	Option B
Electrodes placed under skin, no hospital admission	Electrodes implanted in surgery via buttocks, 1-3 days hospital admission
No effect on continence or number of accidents	Improved continence, but still occasional accidents
Improved voiding, but catheter still needs to be used sometimes	No change in amount of urine you can void
Side effects may include permanently lost sexual sensation, no reflex erections and no self-induced defecation	No side effects
No external device needed to activate neural prosthesis, battery has to be changed every 5 years with minor surgical intervention	No external device needed to activate neural prosthesis, device has to be recharged by yourself every day/week
No out of pocket costs	$400
☐	☐

Suppose you now have the option of no treatment at all, what would you prefer now?

☐ I would still prefer the treatment chosen above
☐ I would prefer no treatment

17. If these were your only treatment options, which would you choose?
Choose by checking on of the options below:

Option A	Option B
Electrodes implanted in surgery via buttocks, 1-3 days hospital admission	Electrodes implanted through surgery in lower part of your spinal cord, about 1 week hospital admission
Improved continence, but still occasional accidents	Complete continence, no more accidents
Complete voiding, no catheterization needed	Improved voiding, but catheter still needs to be used sometimes
Side effects may include occasional discomfort	No side effects
No external device needed to activate neural prosthesis, battery has to be changed every 5 years with minor surgical intervention	External device needed to activate neural prosthesis, has to be recharged every day/week
$150	No out of pocket costs
☐	☐

Suppose you now have the option of no treatment at all, what would you prefer now?

☐ I would still prefer the treatment chosen above
☐ I would prefer no treatment

18. If these were your only treatment options, which would you choose?
Choose by checking on of the options below:

Option A	Option B
Electrodes implanted through surgery in lower part of your spinal cord, about 1 week hospital admission	Electrodes placed under skin, no hospital admission
No effect on continence or number of accidents	Complete continence, no more accidents
Complete voiding, no catheterization needed	No change in amount of urine you can void
No side effects	Side effects may include permanently lost sexual sensation, no reflex erections and no self-induced defecation
No external device needed to activate neural prosthesis, battery has to be changed every 5 years with minor surgical intervention	No external device needed to activate neural prosthesis, device has to be recharged by yourself every day/week
$150	$400
☐	☐

Suppose you now have the option of no treatment at all, what would you prefer now?

☐ I would still prefer the treatment chosen above
☐ I would prefer no treatment

You will now be asked to answer some questions about your personal data. Please encircle the option that applies to you or fill in the answer.

- -

1. What is your gender? Male / female

2. What is your date of birth? _____(mm/dd/yyyy)

3. What is your race?
   1. White
   2. Hispanic or Latino
   3. Black or African American
   4. Multi-racial
   5. Other: _____(please specify)

4. What is your current marital status?
   1. Never married
   2. Married
   3. Divorced/separated
   4. Widow
   5. Living with someone
   6. Other

5. What is your educational level?
   1. Less than 8th grade
   2. Grade School
   3. Some High School
   4. High School or GED
   5. Some College
   6. Associates Degree
   7. Bachelor Degree
   8. Graduate Degree (PhD, MD, JD)

6. What is your current employment status?	1. Employed full-time 2. Employed part-time 3. Self-employed 4. Unemployed, not seeking job 5. Unemployed, seeking job 6. Retired 7. Retired due to injury 8. Student 9. Other
7. What is your current total family income?	1. Less than $5,000 2. $5,000 – $9,999 3. $10,000 – $19,999 4. $20,000 - $29,999 5. $30,000 - $39,999 6. $40,000 - $49,999 7. $50,000 and above 8. Prefer not to respond
8. Do you have help at home?	Yes / no
9. What type of injury do you have?	1. Paraplegia 2. Tetraplegia 3. Cauda Equina
10. Do you have a complete injury?	Yes / no / don't know
11. Do you know the level of your lesion? if yes, what level?	Yes / no _____ (1 character and 1 number)
12. In what year were you injured?	_____

13. What is your current bladder management method?

1. Self-intermittent catheterization
2. Intermittent catheterization with someone's help
3. Indwelling Catheter
4. Continence pads
5. Balanced bladder (tapping, applying pressure)
6. Suprapubic
7. External collection device (condom)
8. Abdominal stoma
9. I do not have bladder problems (proceed to question 22)
10. Other (please specify)

_____

_____

14. If you can urinate, how often do you urinate?
if you do not urinate, proceed to question 17

Daytime: _____ times
Night : _____ times

15. How much time do you spend on urinating? _____ minutes

16. How much time is there between the times you urinate? _____ hours

17. How often do you experience incontinence?

1. Very often
2. Often
3. Sometimes
4. Never

18. Are you being treated for your bladder problems now? Yes / no
if yes, what does this treatment consist of? _____

_____

19. Have you been operated for your bladder problems? Yes / no
if yes, how many times? _____ times

20. Could you provide the name of the intervention/device? _____

_____

21. What was your experience with that operation and the outcome?
1. Positive
2. Neutral
3. Negative

22. Have you ever had surgery for any other problems? Yes / no

23. What was your experience with that operation and the outcome?
1. Positive
2. Neutral
3. Negative

24. Have you experienced any of the following health problems in the last two months?
1. Pressure sores
2. Urinary tract infections
3. Sleep disorders
4. Depression
5. Digestive and intestinal disorders
6. None

- -

This is the end of the survey. Thank you very much for your cooperation.

APPENDIX 2 – CONSENT FORM

Introduction

You are being asked to participate in this research study of user preferences for neural prostheses. Before you can decide whether or not to volunteer for this study, you must be informed of the purpose of the research study, how this study may help you, any risks to you, and what is expected of you. This process is called informed consent.

You do not have to participate in this study. You may stop your participation in this study at any time without changing your current or future relations with MetroHealth Medical Center or its doctors.

If you decide to participate in this study you will be told about any new information learned during the course of the study that might cause you to change your mind about staying in the study. If you withdraw we will still provide you with information regarding possible impacts to your health status or future health care decisions.

Individuals with spinal cord injury are being asked to complete a survey about the choices they would make for neural prostheses to restore bladder function.

Reason for this study

This survey is performed to investigate what method persons with spinal cord injury prefer to restore bladder function. A number of scientific studies have revealed that bladder dysfunction among persons with spinal cord injury has a relatively high negative impact on the quality of life. It has also been investigated that restoration of bladder function would be highly appreciated by persons with SCI.

One of the methods to (partly) restore bladder function is by means of neural prostheses. These devices are being used for a wide range of neuro-rehabilitation treatments, from restoring hearing to reduce tremor. Neural prosthesis involves electrodes that are either placed under the skin or directly on the nerve, and use little currents of electricity to activate specific nerves. In this way, functioning of an organ, in this case the bladder, can artificially be restored by improving continence and voiding. Improvement of bladder function also decreases the risk for urinary tract infections and intermittent high blood pressure (autonomic dysreflexia).

Purpose of the study

At this moment, a lot of different neural prostheses are being developed. However, different neural prostheses have different characteristics. Since the success of a new medical technique highly depends on user satisfaction, this survey is set up to investigate user preferences for neural prostheses that can restore bladder function, thereby enabling researchers to focus on the characteristics that are important to the people that might ultimately be using the neural prosthesis. Eventually, an advanced appreciation of potential user preferences will improve the design of neural prostheses.

This study will take place at 2 places throughout the United States. A total of 79 people will be asked to participate in this study. 49 people will be asked to participate at MetroHealth Medical Center.

What is involved in the study?

Frequency of Visits

For this study, you will be asked to fill out a survey. You do not have to come back to the MetroHealth Medical Center for any follow-up visits.

Duration

The survey will take approximately 30 minutes of your time.

What happens if I discontinue or withdraw from the study?

There will be no consequences if you withdraw from the study before its completion.

What are the risks of this study?

Your participation in this study may involve the following risks:

Emotional and Psychological Risks –

Some of the questions we ask may be upsetting, or you may feel uncomfortable answering them. If you do not wish to answer a question, you may skip it and go to the next question.

Are there benefits to taking part in the study?

There will be no direct benefit to you by taking part in this study. However, we hope the information learned from this study will provide you and other patients with neural prostheses that are adapted to your/their preferences in the future.

What other options are there?

This is a research study. You may decide not to participate.

What are the costs?

There is no cost to you or your insurance company for participation in this study

What happens if I am injured while participating in this study?

Medical care (including hospitalization) is available if you are injured or become ill because of the research procedures. This medical care is not free. You will be responsible for the costs. You may call the Director of Risk Management at (216) 778-5728 if you have any questions about the cost of treatment in your case.

Will I be paid for participating in this study?

You will not be paid or compensated for your participation in this study.

What about Confidentiality?

We will make every effort to keep your research records private, but confidentiality cannot be assured. The MetroHealth System has no control over the use of this information once it is released. The information about you that is collected in this study may be combined with information gathered from public sources or other research studies.

Records that identify you and this consent form may be looked at by a regulatory agency such as:

MetroHealth Institutional Review Board
Louis Stokes Cleveland Department of Veterans Affairs Medical Center IRB
National Committee for Quality Assurance

If the results of the study are published or presented in public, your name will not be used.

The surveys will be stored at Case Western Reserve University, Cleveland, OH for a period of 6 years after the study is completed.

What are my rights as a study participant?

Taking part in this study is voluntary. You have the right to choose not to take part in this study. If you do not take part in the study, your doctor will still take care of you. You will not lose any benefits or medical care to which you are entitled. If you withdraw from the study, with your written permission, clinical data will continue to be collected from your medical records.

If you chose to take part, you have the right to stop at any time. You will be told of any new findings from this or other studies that may affect your health, welfare, or willingness to stay in this study.

If you are an employee or student, whether or not you take part in this study will not affect your job, current or future medical care, or studies.

Whom do I call if I have questions or problems?

If you have questions about any part of the study now or in the future, you should contact Patricia Sanders, who may be reached at (216) 368-8906. If you have any questions about your rights as a research participant, contact the MetroHealth Medical Center's Institutional Review Board (which is a group of people who review the research to protect your rights) at (216) 778-2077.

Patient/Subject Acknowledgement:

The procedures, purposes, known discomforts and risks, possible benefits to me and to others, and the availability of alternative procedures regarding this research study have been explained to me. I have read this consent form or it has been read to me, and I have been given the opportunity to ask questions or request clarifications for anything I do not understand. I voluntarily agree to participate in this study. I have been given a copy of this consent form.

_____ _____
Patient/Subject Signature Date

_____ _____
Signature of Person Obtaining Informed Consent Date

When Applicable:

_____ _____
Signature of Subject Designee Date
[When Subject physically unable to sign – Affirming subject verbal informed consent has been obtained]

APPENDIX 3 – HIPAA FORM

Introduction

You have been asked to participate in the above-named research study, which involves a survey. The following information explains how your research medical information, referred to as "protected health information" or PHI, may be used by the investigators or shared (disclosed) with other people or groups for this research study. Please review this information carefully.

Your decision to allow the use of your protected health information (PHI) is voluntary. If you do not give your permission (authorization) for the use of your protected health information (PHI) you will still be able to participate in this research study.

What PHI will be collected?

If you give permission, Kenneth Gustafson and research staff members under his guidance will collect the following PHI for this study: Demographic information, (name, telephone number, zip code), level of injury, type of injury, year of injury, current level of urinary dysfunction, possible previous operations for bladder dysfunction, and/or previous or current treatment for bladder dysfunction.

Demographic information is collected to enable staff members to contact you in case an answer you provided in the survey is unclear.

Existing information or information created during your participation in this study will be made available by The MetroHealth System (MHS).

Why is this information being collected?

This information is being collected for this study, because the relationship between these aspects and preferences regarding neural prostheses will be investigated.

Who will have access to my PHI and for how long?

In addition to the investigators and staff listed above, your PHI may be looked at by other groups involved with the study such as the MetroHealth Institutional Review Board or authorized representatives from internal hospital operations (for example quality assurance).

Once you give your permission to The MetroHealth System (MHS) to release the information needed for this study, MHS can no longer guarantee your privacy.

The investigators for this study would have access to your PHI collected for this study until six years after the end of the study, at which time it will be destroyed.

Do I have the right to access the PHI requested for this study?

You will have access to the PHI that is related to this study.

If I give permission now for use of my PHI, can I withdraw my permission in the future?

You have a right to withdraw your permission/authorization, at any time. You will be asked to document your withdrawal in writing by completing a Standard MetroHealth Withdrawal Form. All of the PHI that has already been collected about you as part of the study will continue to be used. No new PHI about you will be collected for study purposes unless the PHI concerns an adverse event (bad effect) related to the study.

Authorization (consent) for use and disclosure of PHI for Research

The information in this additional authorization (consent) regarding the use of my protected health information (PHI) for research has been explained to me. I have read this authorization form or it has been read to me, and I have had the opportunity to ask any questions and clarify any information that I do not understand. I voluntarily agree to allow the use and disclosure of my protected health information in this study. I will be given a **signed copy** of this authorization (consent) form.

_____ _____

Patient/Subject Signature Date

_____ _____

Signature of Person Obtaining Authorization Date
When Applicable:

_____ _____

Signature of Subject Designee Date
[When Subject physically unable to sign}