

Survey of cochlear implant user satisfaction with the Neptune™ waterproof sound processor

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Abstract

A multi-center self-assessment survey was conducted to evaluate patient satisfaction with the Advanced Bionics Neptune™ waterproof

sound processor used with the AquaMic™ totally submersible microphone.

Subjective satisfaction with the different Neptune™ wearing options, comfort, ease of use, sound quality and use of the processor in a range of active and water related situations were assessed for 23 adults and 73 children, using an online and paper based questionnaire. Upgraded subjects compared their previous processor to the Neptune™.

The Neptune™ was most popular for use in general sports and in the pool. Subjects were satisfied with the sound quality of the sound processor outside and under water and following submersion. Seventy-eight percent of subjects rated waterproofness as being *very useful* and 83% of the newly implanted subjects selected waterproofness as one of the reasons why they chose the Neptune™ processor.

Providing a waterproof sound processor is considered by cochlear implant recipients to be useful and important and is a factor in their processor choice. Subjects reported that they were satisfied with the Neptune™ sound quality, ease of use and different wearing options.

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Introduction

Cochlear implantation has become the standard treatment for profound bilateral hearing loss with around 50,000 cochlear implant (CI) devices being sold per year. This growing population of adult and pediatric CI users expects to be able to fully participate in their daily lives whilst continuing to hear through their CIs. Indeed, children's knowledge of social interactions often comes *via* passive learning and overheard situations and therefore having access to hearing for as much of the day as possible is vital for this group.¹

The aim of providing a deaf person with a CI is not just to give them access to hearing, but also to enable them to integrate into a hearing world. Studies of psychosocial adjustment in children with sensorineural hearing loss indicate that, along with parent support and good communication skills, participation in extracurricular activities are key ingredients to successful social integration.² A survey by Moog *et al.*, 2011 of 133 high school students who used a CI showed that 94% of them participated in afterschool activities and sports, including water-based activities such as surfing. These activities and sports were similar to those reported by the 46 normal hearing high school students also included in the study. This study highlights the need for manufacturers to provide robust and reliable CI devices which contin-

ue to function during a wide range of activities, including those involving water.

All CI sound processors are worn externally and are at risk of damage from impact and fluid ingress into the electronic circuits. These risks make designing a processor suitable for sports, bath time or swimming particularly challenging because a number of components are particularly vulnerable to liquid damage including microphones, controls and displays and connections between components.³ The degree of protection provided to electrical equipment against moist and wet environments is governed by an ingress protection standard or IP rating. This rating system provides a set of classifications for degrees of protection against solids (such as sand and dust) and water and has two digits: the first describing the protection against solid objects and the second for water.⁴

Currently, the most common type of sound processor sits behind the ear and is vulnerable to being knocked off during active sports. These modern processors also have some protection against fluid damage with an IP rating of 57, allowing the processor to be temporarily immersed in water and to continue to function.³ However, in order to be suitable for activities such as swimming, a rating of IP68 is desired. For ear-level processors, an IP68 can be achieved only with the use of cases or sleeves which physically cover the processor and in particular the microphones, to provide protection from water.^{5,6}

The Neptune™ sound processor specifically has been designed to be suitable for all water based activities, including swimming, with an IP rating of 68. It is a small body worn processor powered with one AAA battery. The Neptune™ and can be attached in many different ways to different parts of the body to allow users flexibility in how it is worn and to facilitate hearing during a wide range of activities, including active sports. The sound processing strategies are the same as those provided by the Harmony and Naída CI Q Series behind-the-ear sound processors including HiRes Fidelity 120™ and ClearVoice™.⁷ The Neptune™ uses a special microphone technology, the waterproof AquaMic™, which is positioned on the side of the head and allows the entire system to be submerged without additional protective covers^{8,9} (Figure 1).

Very little data is available on the preference for and use of water resistant processors by CI recipients, although one study details the technical difficulties that need to be overcome.³ The questions of interest addressed here are whether recipients are satisfied with the products available, if they provide consistent hearing for a range of activities or if providing a waterproof product is considered to be important to them. Therefore, this questionnaire-based survey evaluated the practicality, comfort and ease of use of the Neptune™ processor and its various wearing configurations for daily use as well as during a range of active and water related activities.

Materials and Methods

Subjects

Subjects, implanted with either an Advanced Bionics CII and or HiRes 90K™ cochlear implant, were recruited from clinics in United Kingdom, France, Germany, Italy, Spain, Belgium, The Netherlands, India, Singapore and Hong-Kong. Ninety-six individuals completed the questionnaire voluntarily themselves or through a parent/guardian. Respondents included 23 adults and 73 children. Ages for the adults ranged from 18 to 66 (mean 45 years, standard deviation 14.4 years) and for the children from 12 months to 17 years (mean six years, standard deviation 3.8 years). Fifty-six subjects had experience with other Advanced Bionics sound processors for a minimum of six months and 40 were newly implanted and fitted with the Neptune™ at initial stimulation. Prior to conversion to the Neptune™, 29 existing CI recipients

used the body worn PSP sound processor, 25 used a behind-the-ear sound processors (19 Harmony and 6 Auria). One recipient used both Harmony and PSP speech processor and one both Auria and Harmony speech processor.

Patient consent and procedures were followed in accordance with the ethical standards for human experimentation in each country and with the Helsinki Declaration.

Assessments

A questionnaire was designed by Advanced Bionics to assess subjective satisfaction with the different Neptune™ processor wearing options, comfort and ease of use and sound quality. After answering a set of general questions, each subject was surveyed about the method of processor retention used in the shower, rain, pool, bath and other water related activities as well as for sports, gardening, wearing a helmet and work in sweaty or dusty situations. Retention options were a clip, lanyard, mini and standard pouch, armband, swim headband, swim cap and harness. Not all the wearing options were included in the processor kit of the subjects. They were then asked to rate their satisfaction for each wearing option (if used) on a rating scale of 1-10, where 1 was not at all satisfied and 10 was highly satisfied. Subjects then rated the ease of use of the Neptune™, again on a scale of 1-10 where 1 was very difficult and 10 very easy. Finally, subjects rated their sound quality with the Neptune™ on a scale of 1-10 (where 1 was very bad and 10 was very good) with an FM system, outside water, underwater and following submersion.

Some subjects who had used another Advanced Bionics sound processor completed an additional section comparing the Neptune™ with their previous processor. They were asked if they found the Neptune™ better, worse or similar to their existing processor for sound quality, speech understanding, wearing options, robustness, ease of use, handling, flexibility, design / aesthetics, battery use, battery lifetime and overall. There was also a box for *I do not know/my child is too young to give feedback*.

Procedures

Two versions of the questionnaire were created: an online version, suitable for both new and upgraded Neptune™ users and a paper questionnaire for upgraded subjects. The online questionnaire included two additional questions about overall satisfaction with the Neptune™ and why subjects initially chose to be fitted with the Neptune™. All new and upgraded subjects were asked to use the Neptune™ and to try out the different wearing options for a minimum of four weeks before completing the surveys.

Subjects using an existing Advanced Bionics sound processor were converted to the Neptune™ with no changes to their existing programs in most cases. There were a few subjects upgraded from a Harmony processor to the Neptune™ where most comfortable loudness levels were increased to compensate for the microphone placement on the side of the head. The paper version of the questionnaire was handed out during a routine fitting session, which included the additional questions comparing their previous processor with Neptune™. They were also able to answer the online questionnaire if they chose to.

Newly implanted subjects were switched on according to individual clinic protocols. A paper version of the online questionnaire was also available for new users if access to the Internet was difficult, a particular issue for subjects from India. The bath and pool water related situations were not included in this version of the questionnaire, as this situation is not encountered in the daily life of subjects from this region.

In case of very young children, parents were asked to complete the questionnaire.

Statistics

Since the survey was designed to provide only descriptive information for this population and a non-validated questionnaire was used, no statistical analyses were performed. Results are presented with descriptive statistics such as counts, medians and percentages.

Results

Data from the new subjects who had answered questions on the online survey were combined with data collected from new users from India and the upgraded users who had answered the paper version of the upgrade questionnaire. This procedure ensured that only one set of answers per subject was included in the analysis.

Use in water related situations and active situations

Figure 2 shows the percentage of subjects who reported having tested the Neptune™ processor in the various suggested situations after at least four weeks with the new processor. The most popular activities were sports and in the pool. The most popular wearing option was the clip, which received the highest overall median satisfaction levels of nine out of ten (89 users). All wearing options achieved a minimum median satisfaction score of six and a half out of ten.

Sound quality

When subjects were asked about the sound quality, the range of answers given for use in water were larger than those given for use outside water, indicating that there was more variability in satisfaction when using the processor in the water. Median ratings given for use with and without an FM system were the same. Overall, median satisfaction ratings were greater than the neutral value of five out of ten in all conditions (Figure 3). The sound quality tended towards *very good* with a median rate of 8 out of 10 (N=68) outside water and a same median rating following submersion (N=46).

Ease of use

Subjects also were asked to rate the ease of use/comfort/usefulness of some features of the Neptune™ processor from *very difficult/not comfortable at all/not useful at all* to *very easy/very comfortable/very useful*. Median scores for use of all the different components were above neutral (five out of ten) and tended towards the upper end of the range. Subjects reported that the use of one AAA battery to power the processor was very comfortable/easy to use (median=9). The comfort of the Neptune™ in general was rated highly positively with a median score of eight out of ten as well as the overall level of satisfaction (median=9; rating only by new CI users). The two most difficult tasks were removing the color cover and battery cover, where over 25% of subjects rated these as less than five out of ten. The highest score was for the question *how useful is it to have a waterproof processor*, which had a median score of ten out of ten (92/96 respondents) (Figure 4).

Comparison to the previous processor

Fifty subjects completed the paper questionnaire, which included questions comparing the Neptune™ to their previous processor. Twenty-three users had upgraded from a Harmony or Auria behind-the-ear sound processor and 27 users had upgraded from a Platinum Sound Processor (PSP) body worn sound processor. When compared to the PSP, the Neptune™ was rated as similar or better by more than 80% of the subjects in all areas except battery lifetime. When compared to the Harmony or Auria, the Neptune™ was rated as similar or better by more than 75% of the subjects in all areas except for handling. When

combining both groups of previous type of processors, there was no area in which the Neptune™ was rated worse by more than 31.3% of the subjects.

Sound quality was reported as better for the Neptune™ in 68.4% of previous PSP users and 47.8% scored speech understanding as better with the Neptune™. For the Harmony/Auria users these areas were only scored as better with the Neptune™ by 18.2% and 14.3% of users respectively. The distribution in ratings for the flexibility and design of the Neptune™ processor compared to the previous processor was also different between previous PSP users and previous Harmony users. Indeed, 92% and 100% of the previous PSP users rated the Neptune™ processor as being better than their PSP processor for flexibility and design respectively compared to 61.1% and 74% for the previous Harmony users, although these areas along with wearing options and battery use were the highest percentages of *better* ratings.

Figure 5 shows the percentage of subjects who rated the Neptune™ as better, similar or worse than their previous sound processor for both PSP and Harmony/Auria combined. The majority of the subjects (77.1%) rated the Neptune™ processor as being better overall or in general than their previous processor.



Figure 1. The Neptune sound processor connected to the AquaMic™ microphone.

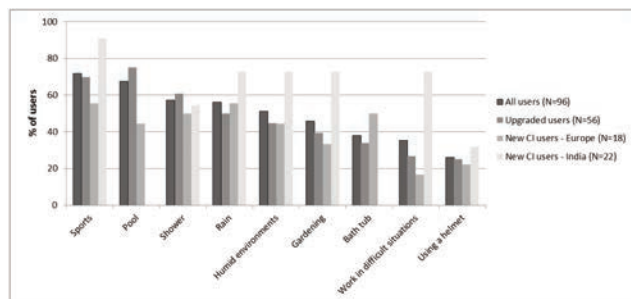


Figure 2. Chart showing on the y-axis the number of subjects reporting that they used the Neptune™ in each of the conditions listed on the x-axis. The first column shows all users and the subsequent columns show the numbers for each of the sub groups (upgraded users, new users from Europe and new users from India). Columns are ranked in order from the highest to the lowest percentage for all groups combined.

Reason for choosing the Neptune™

The 40 subjects who were newly implanted were asked why they chose the Neptune™ processor. A series of closed set options were given: aesthetics, reliability, performance, waterproofness, not applicable (where the Neptune™ had been chosen by the clinic not the user) and other. Subjects could select more than one answer. Two subjects did not answer and for two other subjects, the choice of Neptune™ was made by the center. Eighty-six percent of subjects selected *waterproofness* as one of several reasons why they chose the Neptune™ processor, while 42% selected waterproofness as the only reason they chose the Neptune™.

Discussion

The Neptune™ was worn in a wide range of situations using a variety of retention methods. The highest percentage of subjects used the processor in the pool and for sports. However, depending on experience with the CI (upgraded users or new CI users) and the region of residence (India or Europe), the distribution of subjects differed slightly between groups. Additional comments made at the end of the questionnaire indicated that, in addition to the situations sampled by the survey, the Neptune™ processor was used for sailing, on the beach, at the water park and for canoeing.

Having a waterproof processor was viewed as being an important consideration, independent of the region of residence of the users (warm/humid countries compared to cold countries). Eighty-three percent of the new users reported that *waterproofness* was one of the reasons they chose to have the Neptune™ over another design of Advanced Bionics sound processor (Chi² test, non-significant). When asked *How useful is it to have a waterproof processor*, 78% of subjects rated it as very useful (nine or ten out of ten) (Mann-Whitney U test, non-significant).

Subjects were most satisfied with the clip as the method of attaching the device. The other retention methods were also used successfully

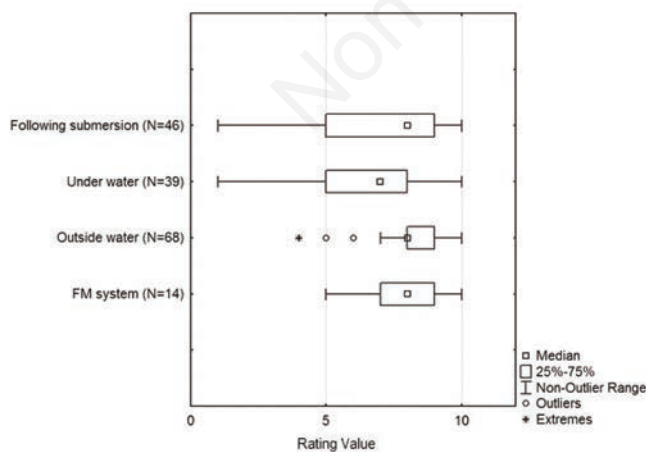


Figure 3. Box plots showing the median ratings for sound quality in four listening conditions listed on the y-axis. The number of subjects in each condition is given in brackets. The x-axis shows the rating value selected from one to ten. Boxes indicate first and third quartile range with the middle box indicating the median value. Whiskers indicate the maximum and minimum values. Two outliers were identified for the outside water condition.

and the majority of subjects were at least satisfied with them.

The sound quality of the processor tended to be rated as being very good under water, outside water and following submersion with median score equal or above seven out of ten. However, the range of responses in water was much wider than for the dry condition, possibly reflecting the smaller sample size (46 and 39 for submersion and under water compared to 68 in the dry condition). Some subjects may not have liked the noisy environment when in the pool and additionally, may not have been prepared for the reduction in sound quality under-water that occurs as a consequence of natural distortion of the input signal.

Subjects were generally satisfied with the ease of use of the processor, with the exception of removing the battery cover. Since this evaluation was conducted, modifications to the battery cover have been made to make it easier to remove.

When compared to the existing PSP body worn processor, most of the upgraded subjects rated the Neptune™ as similar or better in all areas except for battery life. This result is understandable because the PSP is

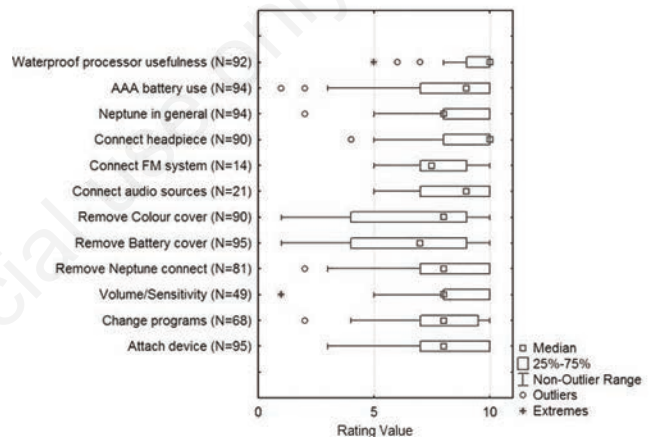


Figure 4. Box plots showing the median ratings for ease of use for 12 functions listed on the y-axis. The number of responses for each function is given in brackets. The x-axis shows the rating value selected from one to ten. Boxes indicate first and third quartile range with the middle box indicating the median value. Whiskers indicate the maximum and minimum values. Outliers were identified for seven of the functions.

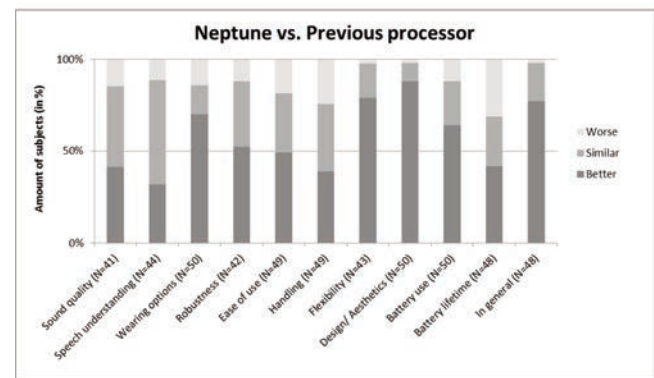


Figure 5. Ratings for the Neptune™ compared to subjects' previous sound processors (PSP and Harmony/Auria data is combined). The y-axis indicates the percentage or responses in that category and the x-axis shows the areas surveyed and the numbers of subjects answering each question.

a significantly larger body worn device that requires a bigger battery. However, when users of a behind the ear processor (Harmony or Auria) were asked to make a comparison with the Neptune™, most subjects rated the Neptune™ as similar or better in all areas except for handling. The strongest benefits for both PSP and Harmony/Auria users were the flexibility and design of the Neptune™, although the effect was much stronger for the PSP users. Battery life was improved for most Harmony/Auria users but was worse for the majority of PSP users. This result reflects the differences in batteries required for each of those processors.

Sound quality and speech understanding were rated as better by a higher percentage of previous PSP users compared to previous Harmony/Auria users. Like the PSP, the Neptune™ microphone position is on the headpiece. However, the microphone on the Harmony and Auria is behind the ear. The difference in microphone placement may explain why fewer Harmony/Auria subjects reported the sound quality as better. In some centers/cases, the most comfortable listening levels were increased to compensate for this microphone placement difference.

Limitations

The study does not report reliability data for the Neptune™ but was designed to survey patients' views and perceptions and thus a comment on the technical reliability of the product cannot be made. The results must also be interpreted in the context of inherent bias in the sample as all participants had already chosen to wear the Neptune™ sound processor. Therefore, any comparisons to existing sound processors were made in retrospect after conversion and thus may have been affected by memory and a natural bias towards the new. However, the majority of subjects found the Neptune™ processor as being similar or even better than their previous processor, showing that it met their expectations. The distribution of age in the population is skewed towards children (around one quarter of adults and three quarters of children) reflecting the tendency for clinics to offer the Neptune™ processor to more children than adults, which was confirmed by feedback provided by professionals during the survey. However, the survey showed that many adults also used the Neptune™ and made use of its flexible wearing options.

The overall comfort and ease of use of the Neptune™ sound processor was rated as being quite comfortable, easy to use (median scores equal or above eight), independent of the type of user (new CI user, upgrade, adults or children) and region of residence (warmer countries compared to colder countries; Mann-Whitney U test, non-significant). Furthermore, the Neptune™ sound processor was overall rated as being highly satisfying by new CI users, both adults and children. Among them, CI users living in colder countries like Germany, The Netherlands *etc.* rated the overall satisfaction as significantly higher than the ones living in warmer or more humid countries like Spain, India *etc.* (Mann-Whitney U test, $P=0.04$). However, median scores were still high for both groups, with respectively scores of 9 and 8 out of 10. When used with the AquaMic™ headpiece, the Neptune™ sound processor enables CI users to hear comfortably outside and under water, providing CI recipients with unlimited hearing in water related

situations. In further studies, it would be interesting to evaluate the AquaMic™ combined with the AquaCase for the Naída CI Q Series¹⁰ in patients preferring to use a behind-the-ear processor.

Conclusions

The survey data show that providing a waterproof processor is considered by cochlear implant recipients to be useful and important and is a factor in their processor choice. The Neptune™ was used for a variety of sports and water based activities, it met subject's expectations and they were satisfied with its sound quality, ease of use and the different wearing options. Overall, the Neptune™ was comfortable and both new and existing adult and pediatric CI users were highly satisfied with it.

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