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D Data interpretation
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F Literature analysis/search
G Funds collection

BENEFIT FROM AN AUDIO PROCESSOR UPGRADE IN EXPERIENCED USERS OF AN ACTIVE MIDDLE EAR IMPLANT: SPEECH UNDERSTANDING IN NOISE AND SUBJECTIVE ASSESSMENT

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Abstract

Background: Microphone directionality plays an important role in speech understanding in challenging acoustic environments. A new audio processor (AP) from Med-El, known as Samba, automatically detects and selects optimal settings depending on the listening situation. This clinical investigation evaluated speech understanding in noise and subjective benefit of an AP upgrade from the prior Amadé to the new Samba.

Materials and Methods: Fourteen Vibrant Soundbridge users with at least 3 months experience with the Amadé AP received the new Samba AP. Speech recognition in quiet was measured using the Freiburger monosyllable test. Speech understanding in noise was assessed using the Oldenburger sentence test. Subjective benefit was determined with the Hearing Device Satisfaction Scale and the Abbreviated Profile of Hearing Aid Benefit.

Results: No differences were detected in pure tone audiometry or speech recognition in quiet between the two audio processors. However, the new Samba AP performed significantly better in challenging noise situations: when speech came from the front and noise from the back, the signal-to-noise ratio (SNR) improved by 3.4 dB with the automatic mode of the Samba AP compared to the Amadé AP. When the sources of speech and noise were switched, a significant improvement of 1.8 dB SNR was observed. Based on the two questionnaires, subjective benefit in daily life and device satisfaction were comparable for the two APs.

Conclusion: Due to its new features, the Samba AP gave significantly better results in challenging acoustical test situations. Even when the direction of background noise changed, the Samba AP performed better due to the new built-in adaptive directional microphones.

Keywords: Vibrant Soundbridge • audio processor • active middle ear implant • hearing loss • speech perception in noise • subjective benefit

BENEFICIOS DE LA ACTUALIZACIÓN DEL PROCESADOR DE AUDIO EN USUARIOS EXPERIMENTADOS DEL IMPLANTE ACTIVO DE OÍDO MEDIO: RECONOCIMIENTO DEL HABLA EN PRESENCIA DE RUIDO Y EVALUACIÓN SUBJETIVA

Resumen

Introducción: El posicionamiento direccional del micrófono juega un papel importante en la comprensión del habla en malas condiciones acústicas. El nuevo procesador de sonido (AP) de la marca Med-El, conocido como Samba, reconoce y selecciona automáticamente los ajustes óptimos en función de la situación de escucha. El presente estudio clínico evalúa la comprensión del habla en presencia del ruido y los beneficios subjetivos provenientes de la actualización del procesador de audio del modelo anterior Amadé al nuevo Samba.

Materiales y métodos: Catorce usuarios del implante Vibrant Soundbridge con al menos 3 meses de experiencia en el manejo del procesador de audio Amadé recibieron el nuevo modelo Samba. El reconocimiento del habla en silencio se midió mediante el test de monosílabos de Freiburger. La compresión del habla en ruido se evaluó mediante el test de oraciones de Oldenburger. Los beneficios subjetivos se valoraron utilizando cuestionarios que evaluaban los beneficios provenientes del uso de los dispositivos de escucha asistida: '*Hearing Device Satisfaction Scale*', así como '*Abbreviated Profile of Hearing Aid Benefit*'.

Resultados: No se detectaron diferencias en la audiometría tonal o en el reconocimiento del habla en silencio entre los dos procesadores de audio. Sin embargo, el nuevo modelo Samba funcionaba mucho mejor en malas condiciones acústicas: cuando el habla llegaba por delante y el ruido por detrás, la relación señal/ruido (SNR) mejoró en 3,4 dB en el modo automático del procesador de audio Samba en comparación con el modelo Amadé.

Con las fuentes del habla y del ruido invertidas, se observó una mejora importante de la relación señal/ruido (SNR), en 1,8 dB. Tomando en consideración ambos cuestionarios relativos a los beneficios subjetivos en la vida diaria y nivel de satisfacción con el dispositivo, los resultados para los dos procesadores de audio fueron comparables.

Conclusiones: Gracias a sus nuevas funciones, el procesador de audio Samba obtuvo resultados bastante mejores en pruebas acústicas desafiantes. Incluso cuando cambió la dirección del ruido que llegaba por detrás, el procesador de audio Samba obtuvo mejores resultados gracias a los nuevos micrófonos direccionales adaptativos.

Palabras clave: Vibrant Soundbridge • procesador de sonido • implante activo de oído medio • pérdida auditiva • reconocimiento del habla en presencia de ruido • beneficio subjeti

ПРЕИМУЩЕСТВА ОБНОВЛЕНИЯ АУДИОПРОЦЕССОРА ДЛЯ ОПЫТНЫХ ПОЛЬЗОВАТЕЛЕЙ АКТИВНОГО ИМПЛАНТА СРЕДНЕГО УХА: ПОНИМАНИЕ РЕЧИ В ШУМЕ И СУБЪЕКТИВНАЯ ОЦЕНКА

Абстракт

Введение: Направленность микрофона играет важную роль в понимании речи в сложных акустических условиях. Новый аудиопроцессор (АР) от компании Med-El, известный под наименованием Samba, автоматически обнаруживает и выбирает оптимальные настройки в зависимости от ситуации прослушивания. Данное клиническое исследование оценивает понимание речи в шуме и субъективные преимущества обновления АР-процессора от предыдущей модели Amadé до новой Samba.

Материалы и методы: Четырнадцать пользователей VibrantSoundbridge с как минимум 3-месячным опытом с АР Amadé получило новый АР Samba. Распознавание речи в тишине было измерено с помощью **Фрайбургского односложного теста**. Понимание речи в шуме оценивалось с помощью **Ольденбургского** фразового теста. Субъективные преимущества определялись с помощью анкет, оценивающих пользу, которая вытекает из использования устройств, улучшающих способность слышать, – 'Hearing Device SatisfactionScale' и 'Abbreviated Profile of Hearing Aid Benefit'.

Результаты: Различия в тональной аудиометрии или в распознавании речи в тишине между двумя аудиопроцессорами не обнаружены. Однако новый АР Samba работал значительно лучше в сложных звуковых условиях: если речь шла спереди, а шум сзади, соотношение сигнал/шум (SNR) улучшилось на 3,4 дБ в автоматическом режиме АР Samba по сравнению с АР Amadé.

При замене расположения источников речи и шума наблюдалось значительное улучшение SNR на 1,8 дБ. Учитывая обе анкеты, касающиеся субъективных преимуществ в повседневной жизни и удовлетворения устройством, можно сказать, что их результаты были сопоставимы для обоих АР.

Выводы: Благодаря новым функциям АР Samba достиг намного лучших результатов в сложных акстических тестах. Даже когда изменилось направление шумов, приходящих сзади, АР Samba достиг более хороших результатов благодаря новым встроенным адаптивным микрофонам направленного действия.

Ключевые слова: VibrantSoundbridg •, звуковой процессор • активный имплант среднего уха • потеря слуха • распознавание речи в шуме • субъективное преимущество vo

KORZYŚCI Z AKTUALIZACJI PROCESORA AUDIO U DOŚWIADCZONYCH UŻYTKOWNIKÓW AKTYWNEGO IMPLANTU UCHA ŚRODKOWEGO: ROZUMIENIE MOWY W HAŁASIE I SUBIEKTYWNA OCENA

Streszczenie

Wprowadzenie: Ustawienie kierunkowe mikrofonu odgrywa ważną rolę w zrozumieniu mowy w trudnych warunkach akustycznych. Nowy procesor dźwięku (AP) firmy Med-El, znany jako Samba, automatycznie rozpoznaje i wybiera optymalne ustawienia w zależności od sytuacji odsłuchowej. Niniejsze badanie kliniczne ocenia rozumienie mowy w hałasie oraz subiektywne korzyści z aktualizacji procesora AP z wcześniejszego modelu Amadé do nowej Samby.

Materiały i metody: Czternaścioro użytkowników Vibrant Soundbridge z co najmniej 3-miesięcznym doświadczeniem z AP Amadé otrzymało nowy AP Samba. Rozpoznawanie mowy w ciszy było mierzone za pomocą monosylabowego testu Freiburgera. Rozumienie mowy w hałasie oceniono za pomocą testu zdaniowego Oldenburgera. Subiektywne korzyści zostały określone za pomocą kwestionariuszy oceniających korzyści płynące z użytkowania urządzeń wspomagających słyszenie 'Hearing Device Satisfaction Scale' oraz 'Abbreviated Profile of Hearing Aid Benefit'.

Wyniki: Nie stwierdzono różnic w audiometrii tonalnej lub w rozpoznaniu mowy w ciszy między dwoma procesorami audio. Jednak nowy AP Samba działał znacząco lepiej w trudnych warunkach dźwiękowych: gdy mowa dochodziła z przodu, a szum z tyłu, stosunek sygnału do szumu (SNR) poprawił się o 3,4 dB w trybie automatycznym AP Samba w porównaniu do AP Amadé.

Przy odwróconym źródle mowy i szumu, zaobserwowano znaczącą poprawę SNR o 1,8 dB. Uwzględniając obydwa kwestionariusze dotyczące subiektywnej korzyści w codziennym życiu oraz zadowolenia z urządzenia ich wyniki były porównywalne dla dwóch AP.

Wnioski: Dzięki nowym funkcjom AP Samba osiągnął znacząco lepsze wyniki w wymagających testach akustycznych. Nawet, gdy zmienił się kierunek szumów dochodzących z tyłu, AP Samba osiągnął lepsze wyniki dzięki nowym wbudowanym adaptacyjnym mikrofonom kierunkowym.

Słowa kluczowe: Vibrant Soundbridge • procesor dźwięku • aktywny implant ucha środkowego • utrata słuchu • rozpoznawanie mowy w hałasie • subiektywna korzyść

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BACKGROUND

Over the last two decades the Vibrant Soundbridge has been developed as a safe and effective treatment for sensorineural hearing loss and has also been successfully applied to mixed and conductive hearing loss [1–2]. This active middle ear implant provides acoustic amplification and transmission of sound energy by coupling a vibratory element, the floating mass transducer (FMT), directly to the vibratory structure of the middle ear.

In order to provide additional benefits – over and above compensating for hearing loss – and to restore more 'natural' hearing, in recent years increasing research effort has been directed towards implant users' perception of sounds, especially spatial hearing and better performance in noisy and challenging environments [3-5]. A drawback when using omnidirectional microphones in hearing aids is the unwanted amplification of background noise, leading to limited speech understanding in this listening situation. In the past, numerous studies involving the simulation and testing of those listening conditions have shown that speech understanding in noise significantly improves when directional microphones are used [6-9]. Directional microphones are beneficial in some listening situations such as communication in noisy environments like restaurants or bars, whereas omnidirectional microphones are more beneficial for hearing traffic coming from the rear or while enjoying music. The second generation audio processor of the Vibrant Soundbridge, the Amadé AP, was released by Med-El in 2009 to allow the user, depending on the listening situation, to switch manually between the standard omnidirectional to the directional setting.

The most recent version of the audio processor for the Vibrant Soundbridge, the Samba AP was introduced by Med-El in 2015. Compared to the Amadé AP, the Samba AP provides a wider range of individually programmable settings as well as improved algorithms to provide better signal-processing features for the user. The Samba AP has a new intelligent system to automatically adapt to the listening situation, omitting the manual switching between omnidirectional and directional modes. A new "full-directional" algorithm has been developed for steering directionality and to overcome the limitations of previous devices. This new feature, called 'Speech Tracking', continuously scans sounds in the listening environment for speech patterns and, as soon as speech is detected, the directivity pattern most effective in focusing that speech source is chosen. The new features of the Samba provide an intelligent hearing system intended to provide users with better and easier handling with the aim of improving quality of life.

The aim of the present study was to compare the audiological performance of the Samba AP to the Amadé AP in challenging noise situations in order to evaluate the benefit of these new features. A comparison of the speech understanding in different situations is clinically important when a patient is being counselled about choice of device. In addition, the subjective benefit was investigated via self-assessment questionnaires.

Materials and Methods

Participants

Fourteen patients were included in this study. There were four female and ten male subjects with a mean age of 56.1 years (SD 13.6) (range 27–71 years). All subjects were implanted with the Vibrant Soundbridge between 2005 and 2014 (Table 1). The patients had normal speech and language skills with a native or very good knowledge of the German language and had used the Amadé AP for at least 3 months for a minimum of 6 hours per day. Only one side was evaluated and the contralateral (not tested) ear was occluded and covered. The study was designed as a prospective single center investigation (Iffland.hören, Ulm, Germany) and approved by the Freiburger Ethics Committee (AP406_Ulm, 014/1602). Informed consent was obtained prior to measurements. Each subject served as their own control. Subjects were evaluated at two visits. First, the hearing performance in the unaided condition was assessed and questionnaires on the Amadé AP were completed. After two weeks of usage of the Samba AP, aided measurements with both audio processors were performed and questionnaires on the Samba AP completed.

Device description

The Vibrant Soundbridge (VSB, Med-El, Innsbruck, Austria) is an active middle ear implant consisting of the implanted vibrating ossicular prosthesis (VORP) and an externally worn audio processor that is held in place magnetically. The audio processor incorporates microphones, a digital signal processing chip, and a battery. It detects, processes, amplifies, and transmits sound to the implant. The VORP is surgically implanted under the skin in the mastoid bone, and the floating mass transducer is coupled to a vibratory structure of the middle ear. Information from the AP is relayed to the implant, which stimulates the middle ear structures through controlled vibrations generated by the FMT and thus stimulates the inner ear. In the present study, two different audio processors were compared: the Amadé AP and its successor the Samba AP. The Amadé AP has been available since 2009 and allows manual switching between a directional mode and an omnidirectional mode. The Samba was launched in 2015 and offers automatic switching between directional and omnidirectional modes and has a novel speech tracking feature.

Prior to use, the audio processor is programmed to meet the particular hearing needs of the individual patient. In order to reduce adaptation effects due to long-term use of the Amadé compared to the short test period with the Samba AP, both audio processors were fitted based on Vibroplasty thresholds only and without further fine-tuning to the patient's needs for the audiologic tests in the present study. Vibroplasty thresholds were obtained through direct stimulation of the implant as an *in situ* measurement as described previously [10,11]. In the present study the Amadé AP was used with the omnidirectional microphone setting for all audiological tests. The Samba AP was used in the automatic (ambient sound) microphone setting (i.e. the universal program) for all tests – except for the OLSA test with noise from the front and speech from

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the back. Here the Samba AP was used with the speech tracking feature activated.

Audiometric tests

Audiometers were calibrated to clinical standards. Speech comprehension and sound field tests were performed via loudspeaker in a sound-treated room, using two loudspeakers at head level. Air-conduction thresholds were measured using warble tones in sound field at 0.25, 0.5, 1, 1.5, 2, 3, 4, 6, and 8 kHz. For speech understanding in quiet, the Freiburger monosyllable test was used at 65 dB SPL. Speech understanding in noise was assessed using the adaptive Oldenburger sentence test (OLSA). Depending on the test setup, a signal with varying sound level and a fixed constant noise level of 70 dB SPL came from front and back loudspeakers (0° and 180° azimuth). The OLSA was used to determine the signal-to-noise ratio (SNR) at which 50% of the presented words were correctly repeated by the subject. For testing performance in background noise, two alternate presentation setups were used: sound coming from the front and noise from the back (S0/N180); and sound coming from the back and noise from the front (S180/N0). The subject was blinded regarding which AP he or she was wearing and the setup 1 or 2 was chosen randomly.

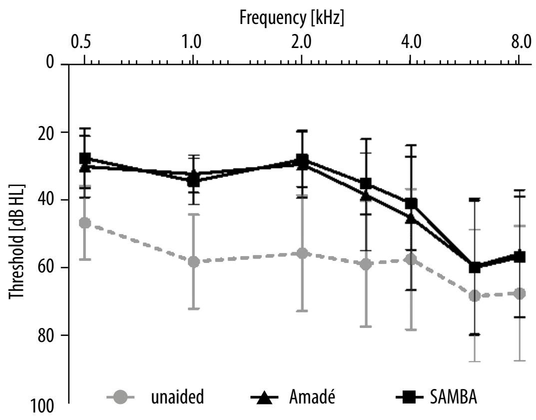

Figure 1. Mean sound field thresholds determined for the unaided condition, and with the Amadé and Samba AP, using warble tones at frequencies of 0.5, 1, 2, 3, 4, 6, and 8 kHz

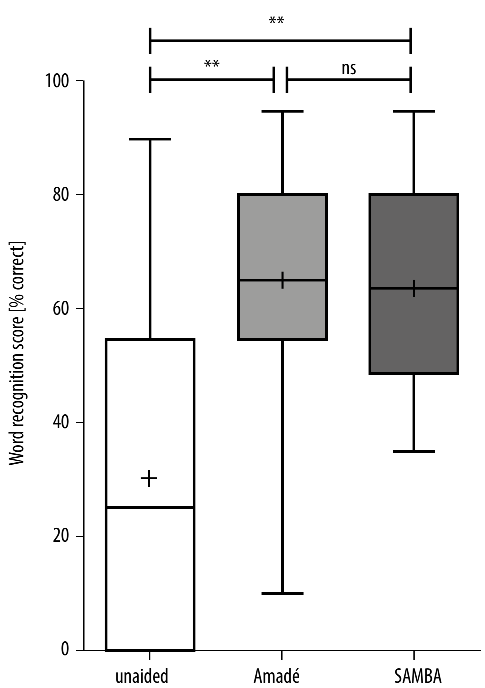

Figure 2. Speech understanding in quiet. Word recognition score (WRS in % correct) in the unaided and aided condition (Amadé and Samba AP) with the Freiburger monosyllable word test at 65 dB SPL. Not significant (ns): $p > 0.05$; **: $p < 0.01$; + indicates mean

Subjective assessment

Two questionnaires were used in this study: the Abbreviated Profile of Hearing Aid Benefit (APHAB) and the Hearing Device Satisfaction Scale (HDSS). The questionnaires for the Amadé AP were completed at the first visit, while responses to the Samba AP were obtained after 2 weeks of initial usage. APHAB comprises a 24-item subjective assessment scale that reportedly measures perceived benefit from amplification. Each item is a statement, and the subject indicates the proportion of time that the statement is true, using a 7-point scale [12]. Three subscales address speech understanding in different environments, i.e. ease of communication (EC), background noise (BN), and reverberation (RV). The subscale aversiveness to sound (AV) assesses negative reactions to environmental sounds. The HDSS was developed by Symphonix to obtain information regarding device use and the subjects' general satisfaction level [13]. It comprises 21 items and is scored using a Likert scale. The answer categories were transformed into a percentage score from 100% (very satisfied) to 0% (not satisfied) based on the answers given.

Statistical analyses

A non-parametric Wilcoxon signed-rank test was used to test for a significant difference between the test conditions in the audiological measurements and the HDSS outcomes. For the subjective measurements with the APHAB questionnaire, a Friedman test with Dunn's multiple comparison test was performed on each APHAB subscale. Statistical significance was defined as $p < 0.05$. GraphPad Prism 6 for Windows 2013, Version 6.02, was used for the analyses as well as for the graphs.

Results

Audiological outcomes

Mean sound field thresholds (at frequencies of 0.5, 1, 2, 3, 4, 6, and 8 kHz) obtained for the unaided condition were 58.6 dB (SD 7.5) and improved when aided with the Amadé to 41.3 dB (SD 12.9) and with the Samba to 40.4 dB (SD 13.2). No significant difference in sound field measurements could be observed between the two audio processors ($p = 0.39$) (Figure 1).

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The mean unaided word recognition score in quiet was 30.4% (SD 29.6) and improved significantly to 65.0% (SD 22.2) with the Amadé and to 63.6 % (SD 18.8) using the Samba ($p < 0.001$). No significant difference could be observed when comparing the two audio processors against each other ($p = 0.38$) (Figure 2).

In the OLSA S0/N180 situation, when speech was coming from the front and noise from the back, use of the Amadé AP gave a significant improvement in SRT. Compared to the unaided condition of 9.7 dB SNR (SD 6.2), use of the Amadé AP gave an SRT of 5.9 dB SNR (SD 4.7) ($p = 0.0097$). In the same test, use of the Samba AP gave a further improvement to 2.3 dB SNR (SD 5.2) ($p = 0.0001$) (Figure 3A). Results for the Samba were significantly better compared to the Amadé ($p = 0.017$). Compared to the unaided condition, a mean benefit in SNR of 3.5 dB (SD 4.1) was achieved with the Amadé and of 6.9 dB (SD 4.9) with the Samba, i.e. an improvement in SNR of 3.5 dB was achieved with the audio processor upgrade ($p = 0.0134$).

When speech understanding in noise was assessed with speech coming from the back and noise from the front (S180/N0), the mean SNR improved significantly (Figure 3B), falling from an unaided 8.4 dB SNR (SD 7.3) to 2.9 dB SNR (SD 5.3) for the Amadé ($p = 0.0061$) and to 1.1 dB SNR (SD 4.4) for the Samba ($p = 0.0001$). The mean benefit in SNR compared to the unaided condition was 5.6 dB (SD 5.9) for the Amadé and 7.4 dB (SD 4.9) for the Samba, i.e. an improvement of 1.8 dB was observed in this setting in favor of the Samba ($p = 0.0353$).

Subjective outcomes

APHAB. Both the Amadé and Samba scored significantly better on all four subscales ease of communication (EC), background noise (BN), reverberation (RV), and aversiveness (AV) than in the unaided situation. Also the global score was significantly better for both audio processors than in the unaided situation ($p = 0.0007$) (Figure 4).

When we assessed whether the sound processor upgrade had an effect on hearing ability in daily life of the subjects we found that the mean APHAB score remained stable on the BN subscale (Amadé 40%, SD 15%; Samba 40%, SD 18%), improved in the RV (Amadé 32%, SD 20%; Samba 27%, SD 21%), and decreased in the EC (Amadé 16%, SD 17%; Samba 22%, SD 14%) and AV subscale (Amadé 38%, SD 30%; Samba 31%, SD 29%). None of these differences was statistically significant. Also, no significant difference between the APs in the global score was observed ($p > 0.9999$) (Figure 4).

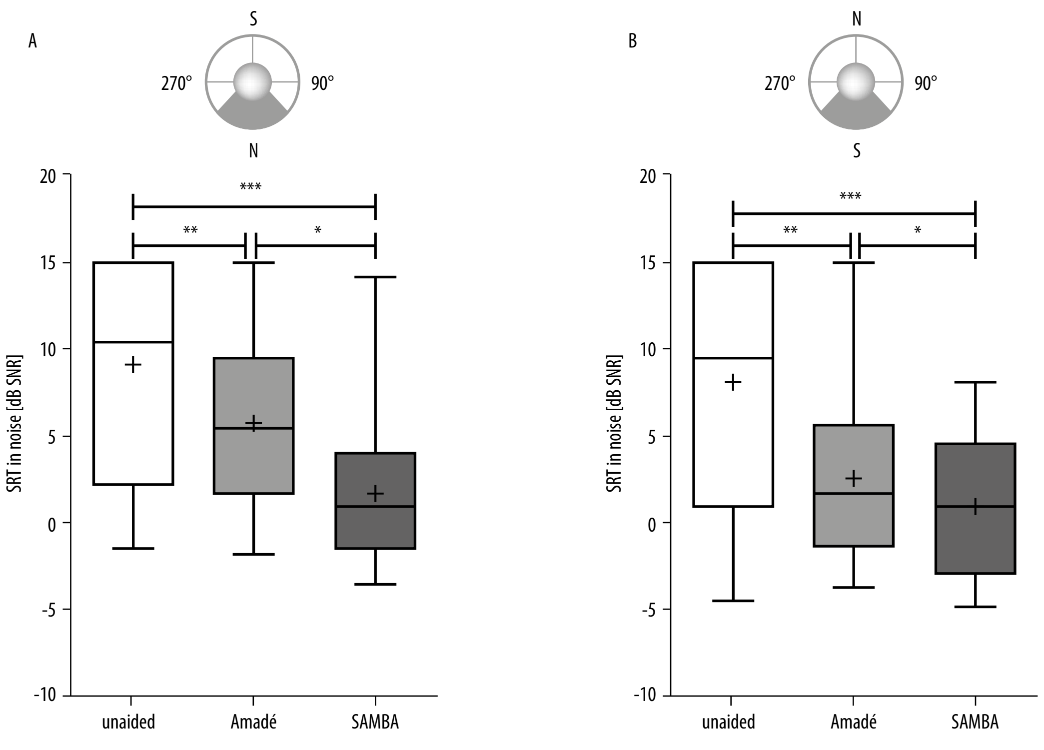

Figure 3. Speech understanding in noise using the Oldenburger sentence test (OLSA), showing the mean signal-to-noise ratio (SNR) at which a subject understands 50% of the presented words at a fixed noise level of 70 dB SPL. **A.** Speech (S) coming from the front and noise (N) from the back (S0/N180). Both audio processors tested in their standard programs. **B.** Speech coming from the back and noise from the front (S180/N0). Amadé AP in its omnidirectional mode. Speech tracking feature of Samba AP activated. *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$; + indicates mean

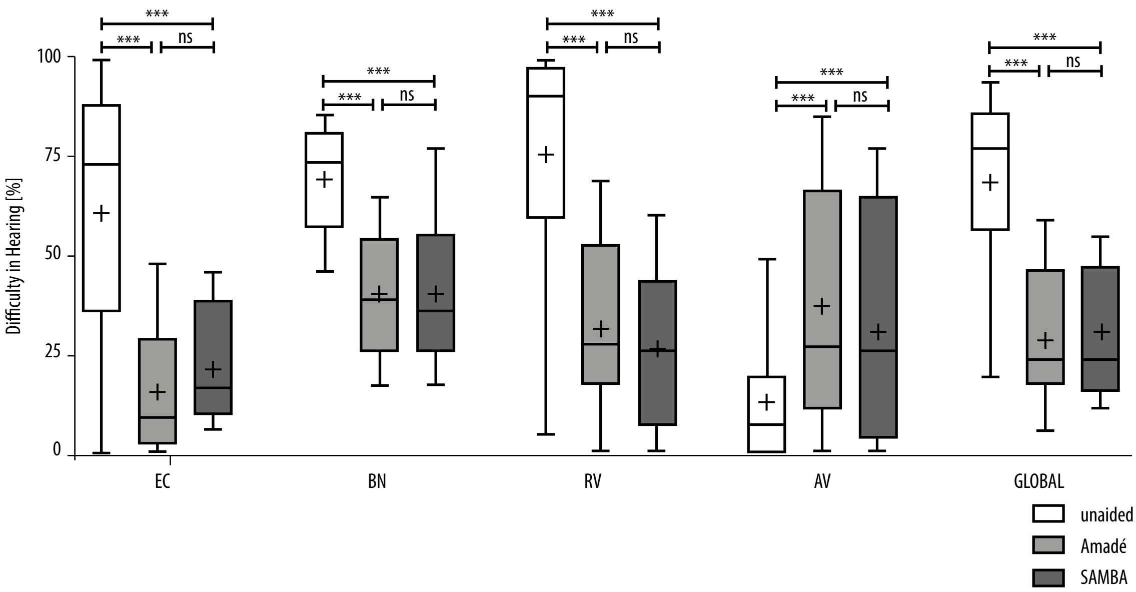

Figure 4. APHAB questionnaire scores for the unaided condition (white), Amadé AP (light grey), and Samba AP (dark grey) showing subscores for ease of communication (EC), background noise (BN), reverberation (RV), aversiveness of sounds (AV), and the global score (global). Not significant (ns): $p > 0.05$; *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$; + indicates mean. APHAB, Abbreviated Profile of Hearing Aid Benefit

HDSS. All subjects completed the HDSS questionnaire examining Sound Quality and Usability. The outcomes for Sound Quality as well as Usability were not significantly different between the two audio processors (78% vs 80%, $p = 0.6528$, and 72% vs 66%, $p = 0.0972$ for the Amadé and Samba, respectively) (Figure 5). Furthermore, the results showed great variations in the subjective state of Feeling.

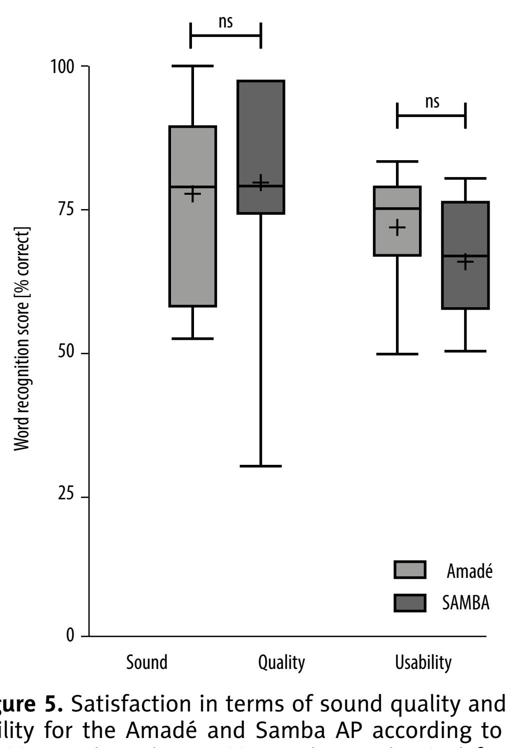

Figure 5. Satisfaction in terms of sound quality and usability for the Amadé and Samba AP according to the HDSS questionnaire. HDSS, Hearing Device Satisfaction Scale. Not significant (ns): $p > 0.05$

Discussion

No significant difference in the aided free-field thresholds between the two audio processors was observed. The mean functional gain for the Amadé AP was 19 dB and for the Samba AP 18 dB. This was expected, as there is no difference in output and gain characteristics between the two devices. Also speech understanding in quiet at conversational level was comparable, reflected by a similar mean WRS of 65% and 64%, respectively. This data is in accordance with the literature. In recent publications the functional gain varied between 19 and 54 dB, depending on the population studied [14-17]. In the aided condition, a WRS at conversational level of 64–85% was achieved in larger cohort studies [14, 18, 19]. Maier et al. reported a mean functional gain in long-term users (4–8 years) of the Vibrant Soundbridge of about 18 dB and a WRS of about 60% [20]. However, users reported softer and more natural sound by the Samba AP, probably due to the new integrated chip and better speech processing capabilities.

In order to evaluate the benefits of the new features of the Samba, two test set-ups to determine speech understanding in noise were evaluated. In the first test, speech came from the front and noise from the back and both audio processors were compared using their specific standard programs (i.e. the omnidirectional setting of the Amadé compared to the automatic/ambient sound mode of the Samba which enables automatic adaptation to an omnidirectional or directional microphone setting depending on the detected ambient sound). Compared to the Amadé, a

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mean improvement of 3.4 dB SNR was observed for the Samba. Thus, the Samba effectively recognized the sound situation and chose the optimal microphone setting. This provides a considerable benefit to users in their day-to-day routine by eliminating the necessity to switch manually between programs. The advantage of directional versus omnidirectional microphones has been evaluated previously. Wolframm et al. tested the Amadé in its omnidirectional mode compared to its directional mode and found an improvement of 4.6 dB SNR [4]. In another middle ear implant system, the direct acoustic cochlear implant (DACI), the use of the directional microphone mode was also found to improve speech understanding in noise by 4.7 dB SNR [21]. In a study with an osseointegrated bone conduction device, Kurz et al. measured a mean improvement of 2 dB SNR when using the directional compared to an omnidirectional microphone setting [22]. The limiting factor of these studies is that all the changes in setting required a manual switch of the audio processor program. We present here the first data, to the best of our knowledge, on the automatic selection of the most suitable microphone settings based on the detection of ambient sound in an active middle ear implant system. With this automatic setting a comparable result to the manual switching of the program based on the test situation could be achieved.

The second test set-up for speech understanding in noise aimed to evaluate the effect of the speech tracking feature of the Samba AP. A S180/N0 arrangement was employed to demonstrate that in this condition the speech tracking feature provided benefits by changing the directionality to a backward directional microphone setting. In this set-up an improvement of 1.3 dB SNR was observed using the Samba compared to the Amadé.

For the OLSA test, Wagener et al. correlated the improvement in SNR to the improvement in speech discrimination score: at the 50% speech intelligibility level, an improvement in speech discrimination of about 17.2% can be expected per 1 dB SNR improvement [23]. Based on these correlations, an improvement in speech intelligibility of about 60% could be achieved with the Samba compared to the Amadé in the S0/N180 setting and of about 20% in the S180/N0 setting.

Although the subjective perception investigated via the APHAB and HDSS questionnaires showed a high satisfaction level from the unaided to the aided condition, no significant differences between the two audio processors could be observed. This might be due to the use of questionnaires which were not sensitive enough or to the fact that the wearing/acclimatization time of 2 weeks for the Samba was not long enough to give a meaningful difference (despite the statistically significant benefit of the Samba in the audiological test in noise). The APHAB is intended to measure the outcome of hearing aid fittings, comparing alternative fittings and tracking the success of a fitting over time. The discrepancy between the positive and significant audiometric results and the insignificant subjective evaluation might indicate that listening tests in soundproof test rooms do not reflect the real-life perception of an individual, or that is not sensitive enough. Despite the best fitting and audiological outcomes, it is likely that residual disability and handicap will be seen even after a ‘successful’ hearing-aid fitting and will affect the satisfaction of the device wearer [24]. Satisfaction is a complex variable [25] and includes elements that are often not addressed explicitly in hearing rehabilitation programs, nor satisfactorily investigated via questionnaires.

Table 1. Patient characteristics

Subject no.	Age (yrs)	Gender	Implant side	Implanted in (year)	MEI use per day (h)	HL type at implanted ear	PTA4 AC, unaided	PTA4 BC, unaided	HL type contralateral
1	27	male	right	2010	24	CHL[1]	75	6.25	NH
2	30	male	right	2012	24	MHL	56.25	48.33	MHL
3	64	male	left	2012	24	SNHL	48.75	36.25	SNHL
5	66	female	left	2013	6	MHL	67.5	52.5	MHL with HA
6	52	male	right	2004	16	SNHL	45	36.25	SNHL
7	47	male	left	2007	6	SNHL	42.5	30	NH
8	68	male	left	2005	24	SNHL[2]	48.75	42.5	SHNL
9	46	male	left	2014	24	CHL	30	6.25	CHL
10	64	male	left	2010	14	SNHL	70	52.5	SNHL with HA
11	69	male	right	2005	14	SNHL	50	40	SNHL
12	56	female	left	2014	18	SNHL	43.75	43.75	SNHL
13	71	female	left	2013	24	MHL[3]	72.5	40	NH
14	66	female	right	2009	16	MHL	40	27.5	MHL
15	60	male	left	2012	24	SNHL	75	67.5	SNHL
Mean	**56 ±14**				**18.43 ±6.66**		**54.64 ±14.74**	**37.83 ±16.77**	

AC, air conduction; BC, bone conduction; HL, hearing loss; MEI, middle ear implant; PTA4, pure tone average at 0.5, 1, 2, and 4 kHz; SNHL, sensorineural HL; MHL, mixed HL; CHL, conductive HL; NH; normal hearing; HA, hearing aid; [1], atresia; [2], 12 previous surgeries; [3], tinnitus

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Conclusion

The technology to restore hearing has improved markedly over the past years. The new features of the next generation Samba audio processor provide a significantly better performance in challenging listening situations in noise compared to its predecessor, the Amadé. The automatic mode of the Samba AP selects the optimal microphone setting – directional or omnidirectional – based on environmental sounds, providing a significant advantage to the user when the direction of noise and sound is changed in an audiological test situation. There was a high degree of subject satisfaction as well as improvement in hearing performance with both devices. However, further investigations are necessary to get a more complete picture of the users' hearing benefit in everyday listening situations.

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