SmartHand: A Sense of Assistive Devices

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Résumé :

(traduction)

Les amputés doivent souvent affronter une stigmatisation sociale parce qu'il est évident aux yeux de tous qu'ils ont perdu un membre ou qu'ils utilisent une prothèse. Cependant, l'utilisation de prothèses a fait beaucoup de progrès au cours des dernières années, surtout en ce qui concerne les prothèses sensorielles. Plusieurs réseaux d'information ont récemment fait des reportages à propos d'un appareil de ce type, un nouveau prototype appelé la SmartHand. Dans la discussion, l'auteure analyse la SmartHand et la compare avec les plateformes existantes, et notamment avec les prothèses myo-électriques et avec la ré innervation musculaire ciblée. L'auteure conclut que la SmartHand offrait un niveau plus élevé de compétences à ses utilisateurs et améliorait leur qualité de vie. Toutefois ses conclusions soulignent aussi les obstacles scientifiques qui se posent, surtout au niveau du rejet tissulaire. L'analyse coût-avantage d'un tel appareil risque aussi de produire des données contradictoires, ce qui pourra nuire à sa mise en œuvre à une plus large échelle. Malgré ces problèmes, la SmartHand est un des appareils fonctionnels disponibles aujourd'hui les plus avancés sur le plan scientifique, et son utilité pour les amputés est indéniable.

Mots-clés : Technologie d'appareils fonctionnels, invalidité, amputés, prothèses myoélectriques

Abstract:

Amputees have often faced social stigma attributable to their visible limb loss or use of artificial substitutions. In recent years, the use of prosthetics has become much more advanced, particularly in the field of sensory prostheses. One such assistive device, a new prototype technology known as the SmartHand, has recently been featured on several news networks. It is through this discussion that the SmartHand will be reviewed and compared with existing platforms that include myoelectric prostheses and targeted muscle reinnervation. Use of the SmartHand has been noted as having increased levels of competence in and improved the quality of life of its users. These conclusions also bring to light the scientific barriers that are faced, primarily with respect to tissue rejection. The cost benefit analysis of such a device may also produce conflicting data, thereby making it difficult to implement this device on a larger scale. Despite these problems, the SmartHand represents one of the most scientifically advanced assistive devices available in today's market, whose usefulness for amputees is undeniable.

Keywords: Assistive device technology, disabled living, amputees, myoelectric prostheses

Introduction

One of the fundamental characteristics that define us as human beings is our hands. The complexity of motion and sensation made achievable through them is an unparalleled way in which people are able to interact with and experience the world. As such, the loss of these limbs from accidents or disease processes is a devastating loss to both a person's psyche and quality of life. In accordance with the International Classification of Health, an amputation represents a loss of body structures, wherein the consequent implication on an individual's level of activity and participation in society are enormous (Scherer, Jutai, Fuhrer, Demers, & Deruyter, 2007). To this end, amputee assistance is imperative as over two million people with lost limbs currently live in North America (Ziegler-Graham, MacKenzie, Ephraim, Travison, & Brookmeyer, 2008). Artificial limbs have long been the primary means of response for amputees. These substitutions are classified as assistive devices because they increase the ability of these individuals to perform daily tasks with greater proficiency (Scherer et al., 2007). The first prosthetics began as hook attachments and cable limbs but have since progressed to prostheses that allow for multifunctional control (Parker, Engelhart, & Hudgins, 2006). Subsequently, the current state of prosthetic technology regarding lower arm and hand functioning revolves around myoelectric prostheses. This type of device allows for the transmission of electromyographic (EMG) signals along remaining neurons to allow for possible motion (Weir, Troyk, DeMichele, & Kerns, 2005). In this capacity, residual muscle nerves are kept packaged within the remaining portion of the salvaged limb, wherein these nerves are then appropriately connected to proximal muscles and controlled by stimulation of electrodes in the prosthetic hand (Weir et al., 2005).

Over the past decade, most substantial refinement and marked progress in myoelectric prostheses has steadily continued in the area of complex movements. Comparatively, a desired function that is often overlooked by the majority of disabled individuals is improved sensation feedback (Pylatiuk, Schulz, & Doderlein, 2007). It is apparent that the inability to distinguish between the two areas of feedback, force and temperature, can be crippling to amputees (Pylatiuk et al., 2007). The significance of feeling includes motor functions; as movements become more precise, an individual requires responsive pressure feedback to execute skills with greater accuracy. A recent development to meet this need is provided by the SmartHand, which allows for in-depth "feeling". This device is still in the prototypic stages but has been in production for over a decade and is expected to be released within two years (Tutton, 2009). There have been minor advancements in sensory prosthetics in the past, especially using a system known as targeted muscle reinnervation (TMR) that uses chest muscles to permit feeling and movement (Miller, Stubblefield, Lipschutz, & Kuiken, 2008). Nonetheless, no existing technologies provide pressure feedback and feeling comparable to the SmartHand (Antfolk, Balkenius, Rosen, Lundborg, & Sebelius, 2010). As a prosthetic living support technology, the usefulness of the SmartHand needs to be judged on its ability to balance this novel innovation without comprising other functions. Aspects such as size, expenses, maintenance, and applicability to the amputee population are all areas that must be considered. One of the complaints of TMR technology was the perception of less natural- seeming sensations (Antfolk et al., 2010). As a result, if new technology such as the SmartHand cannot restore function in a practical way, it will not necessarily be of any benefit to the recipient. The SmartHand represents a tentative and intriguing advancement for the existing self -support technology of powered prosthetics.

Summary of the SmartHand

In a recent news article by Cable News Network (CNN) published in November 2009, the SmartHand is touted as a revolutionary piece of technology that will be amongst the most advanced prosthetic limbs available. The basis for the technology relies on the use of EMG signals from current myoelectric prostheses to activate motors found in the robotic fingers. The crucial distinction is that the SmartHand also allows for sensory information to be detected and transmitted from numerous sensors within each finger that permit for the actual sensation of touch. The sensory motors are then able to sense both pressure and force and transmit that information to actuators in the arm. Actuators must be targeted in order to match a given area of the finger with the correct nerve. In doing so, it allows for direct transmission to and activation of the part of the brain associated with that muscle. The brain then interprets the neuroelectrical impulse as a sensation of feeling in the "hand". A limitation is that the SmartHand will only be available for amputations done below the elbow as any limb lost above that point does not have enough muscles remaining to control the prosthetic with a sufficient degree of precision (Tutton, 2009). A second, more pertinent, limitation is the difficulty of attaching several electrodes to the nerves remaining in the stump, known as the residuum. Since the placement requires exact measurements, any discrepancies make it difficult to discern between the feelings of two adjacent fingers. The appropriate solution under such circumstances is a neural interface similar to the current myoelectric system, which utilizes direct nerve attachment as opposed to focusing on muscles (Tutton, 2009). Moving away from larger muscles thereby allows for increased accuracy. Currently, the project uses an external transmitter fitted onto the arm as a prototype (Antfolk et al., 2010). If a neural interface method were implemented, it would have to be implanted into the individual causing concerns over biocompatibility.

Analysis

The SmartHand must initially be analysed on the basis of scientific evidence. The basis for the SmartHand pertains to its objective of directly routing nerve signals to the brain, which forms the critical point of difference from the competing technology in TMR signals. Targeted muscle reinnervation deinnervates muscles that are rarely used, specifically the pectorals. A subsequent redirection of nerves to that area produces the sensation of being touched on the arm when pressure is applied to the corresponding area of the chest (Marasco, Schultz, & Kuiken, 2009). Unlike the SmartHand, the difficulty in TMR lies in harnessing this sensory capacity into a more practical medium. Tutton (2009) stresses that the mechanism by which the nerve signals can be received by the SmartHand lies in the phantom limb. This is the basis of the TMR framework. More specifically, this phantom phenomenon describes the sensations that individuals experience originating from the lost body part (Hunter, Katz, & Davis, 2005). Tutton's news article (2009) also emphasizes the exploitation of these phantom experiences, as an amputee will continue to send nerve signals to corresponding neurons as if the limb was still present. The parallels between the two technologies can be difficult to distinguish, as Tutton (2009) further suggests that TMR methodology was considered prior to the neural interface. However, SmartHand technology is focused on attaching electrodes to nerve bundles in the residuum as opposed to regenerating nerves in the pectoral muscles. With a line of attachment through a neural interface, the nerves can be stimulated directly. Since phantom limb experiences indicate that the correct sensory motor cortex areas remain active, the brain can continue to receive these signals. An important problem to highlight is that every individual interprets phantom limb pain in a unique way, and some individuals do not experience the phenomenon to any degree (Hunter et al., 2005). Tutton (2009) fails to address this point, which makes it increasingly difficult to apply this technology on a broader scale. Each individual not only has to have the prosthetic matched with the correct nerves but must also have it calibrated to match the phantom limb sensory map. As such, the resulting use of this technology may be disproportionate in the population.

As a neural model is required for the SmartHand to perform optimally, unique challenges are presented. Since the interface requires a direct implantation into the human body, an initial claim of biocompatibility needs to be discussed. Similar to transplants or tissue related technologies where biological tissues need to be combined with synthetic materials, the possibility of rejection remains important to consider (Peramo & Marcelo, 2010). If the body is not compatible with such a device, illness will be observed in addition to the prosthetic being rendered non-functional (Tutton, 2009). An additional challenge to placing a device inside the body is that unlike tissues or stem cells, which can be autologous, the machine is a completely foreign object (Peramo & Marcelo, 2010). In this sense, this challenge is the largest scientific barrier to the full implementation of the SmartHand in the health care market. What is more is that the news report notably fails to discuss the sociological implications of implanting the interface. In Canada, any implanted product would automatically be classified as a Class III device, posing a moderate risk should the device fail to function correctly (Canadian Agency for Drugs and Technologies in Health, 2007). This would likely be an upgrade in classification as most prosthetic devices are non-invasive with the exception of initial reinnervation surgery. Any increase in risk to the patient should always be taken seriously and a cost-benefit analysis must be completed accordingly. Given the rigorous procedure associated with neural implantation, a higher associated cost would be expected. As the average price of a prosthetic limb in North America can reach upwards of twenty thousand dollars, the SmartHand would likely surpass current prices (Chung, Oda, Saddawi-Konefka, & Shauver, 2010). This cost would be further compounded by costs associated with routine and surgical maintenance to replace or alter the prosthetic as it ages with the patient. Providing an alternative to the neural model is impossible since Tutton (2009) states that the interface must be refined before the system can be considered commercially viable, which reflects that the neural model is not only necessary for optimal functioning but is a foundational requirement of the SmartHand. The financial cost in acquiring and maintaining the SmartHand would become one of the major factors inhibiting the growth and spread of this new technology (Scherer et al., 2007). The possibility of regaining feeling in one's limbs is significant, but whether or not it is worth the price tag over a less expensive and invasive substitute remains unclear. Consequently, providing this device to all members of society may profoundly limit its use in the amputee population.

A final point of discussion pertains to the convenience and utility of the SmartHand in daily life as an assistive living technology. As previously reported by the news report, the device is grounded in myoelectric prostheses. To this end, the SmartHand is at least as functionally valuable as the current motorized limbs in allowing an individual to perform basic movements. The vast majority of current prostheses are generally one single degree of freedom or multi-movement machines that are slow and limited (Weir et al., 2005). Although the news report does not provide commentary on the speed of the SmartHand, it does note the allotment of individual finger control. Coupling this ability with exceptional sensory feedback mechanisms would allow for actions such as eating and writing, which require fine motor precision (Antfolk et al., 2010). Since the pressure sensations allow an amputee to manipulate varying degrees of force using their prosthetic, the status of the SmartHand as an assistive device is superior to that of current technology. Furthermore, due to the nature of a prosthetic as a substitute for a body part, the SmartHand would also be able to transition into support for social activity. The presence of a functioning hand allows for both vocational and recreational provisions because regaining mobility undoubtedly allows for enhanced participation in society (Scherer et al., 2007). Using the competence-press model proposed by Lawton, this device would produce a positive effect on adaptive behaviour. Comparatively, less advanced prosthetics would demonstrate lower competence in an equal press environment, thereby placing it in a category of marginally adaptive behaviour (Scherer et al., 2007). Even in comparing basic motor function capabilities, Tutton (2009) states that TMR requires the activation of chest muscles to control arm function. The rate of learning new movements and harnessing these unused muscles depends on each individual's sensory motor reorganization post-amputation (Antfolk et al., 2010). In contrast, the neural interface proposed does not have this difficulty. If the anticipated neural system in the article comes to fruition, this also would also allow the device to lessen social stigma. One of the detriments of using an assistive device is that it reinforces a disabled status and adds a social pressure (Scherer et al., 2007). Although the SmartHand may not eliminate this stigmatization, it may serve to reduce it as the SmartHand represents a step towards affirming the status quo.

Conclusion

The development of the SmartHand has culminated in a powerful new technology that has the potential to become the next step in modern prosthetics. Given its strong basis in the present robotics of myoelectric prostheses, the SmartHand is able to build on existing functionality with the addition of sensations. As previously mentioned, the claims put forth by the news report regarding the state of affairs in the scientific field are justified. Theoretically, implementing a neural interface into an individual's arm would overcome the sensory problems encountered by the TMR prosthetic. Notably, however, Tutton's emphasis on phantom limb experiences may not be plausible in all amputees (Tutton, 2009). Still, the science and efficacy behind the SmartHand can be deemed valid as the inferences of both sensory feedback and multifunction control result in an improved assistive living device. The greatest problem with the SmartHand, as claimed in the news report, was the issue of biocompatibility. The resulting risks are shown to be quite significant as a biological barrier to integrating the device inside a human arm. The news story problematically omits the possible cost implications of this neural interface. Additional research has demonstrated the disproportion in usage this would likely create within the target population, which would prove to be damaging in the long term. As Tutton (2009) proposes, the main research priority is to overcome rejection of the device by the body. Although progress has been made through successful transplantation in animal experiments, research efforts must be extended to include human models. Most importantly, because the neural interface remains largely theoretical until it can be implemented in human patients, the claims regarding the model have yet to be validated. Additionally, information pertaining to costs should be substantiated to determine whether or not the price will become an insurmountable leap for the majority of patients to make. Implementation of healthcare programs and subsidizations may help control for this limitation and promote the growth of this technology (Scherer et al., 2007). In spite of these challenges, the SmartHand is a remarkable device that will provide essential information for the advancement of bioengineering in prosthetics.

References

Antfolk, C., Balkenius, C., Rosen, B., Lundborg, G., & Sebelius, F., Smarthand tactile display: A new concept for providing sensory feedback in hand prostheses. *Scandinavian Journal of Plastic and Reconstructive Surgery and Hand Surgery, 44*(1), 50-53. doi: 10.3109/02844310903259090

Canadian Agency for Drugs and Technologies in Health. (2007). Medical device regulation in Canada: A primer. Retrieved from http://www.cadth.ca/products/environmental-scanning/health-technology-update/health-technology-update-issue5/medical-device

Chung, K. C., Oda, T., Saddawi-Konefka, D., & Shauver, M. J. (2010). An economic analysis of hand transplantation in the United States. *Plastic and Reconstructive Surgery, 125*(2), 589-598. doi: 10.1097/PRS.0b013e3181c82eb6

Hunter, J. P., Katz, J., & Davis, K. D. (2005). Dissociation of phantom limb phenomena from stump tactile spatial acuity and sensory thresholds. *Brain, 128*(2), 308-320. doi: 10.1093/brain/awh350

Marasco, P. D., Schultz, A. E., & Kuiken, T. A. (2009). Sensory capacity of reinnervated skin after redirection of amputated upper limb nerves to the chest. *Brain, 132*(6), 1441-1448. doi: 10.1093/brain/awp082

Miller, L. A., Stubblefield, K. A., Lipschutz, R. D., & Kuiken, T. A. (2008). Improved myoelectric prosthesis control using targeted reinnervation surgery: A case series. *IEEE Transactions on Neural Systems and Rehabilitation Engineering, 16*(1), 46-50. doi: 10.1109/TNSRE.2007.911817

Parker, P., Englehart, K., & Hudgins, B. (2006). Myoelectric signal processing for control of powered limb prostheses. *Journal of Electromyography and Kinesiology, 16*(6), 541-548. Retrieved from http://www.jelectromyographykinesiology.com/

Peramo, A., & Marcelo, C. L. (2010). Bioengineering the skin-implant interface: The use of regenerative therapies in implanted devices. *Annals of Biomedical Engineering, 38*(6), 2013-2031. doi: 10.1007/s10439-010-9937-1

Pylatiuk, C., Schulz, S., & Doderlein, L. (2007) Results of an internet survey of myoelectric prosthetic hand users. *Prosthetics and Orthotics International, 31*(4), 362-370. doi: 10.1080/03093640601061265

Scherer, M., Jutai, J., Fuhrer, M., Demers, L., & Deruyter F. (2007). A framework for modeling the selection of assistive technology devices (ATDs). *Disability and Rehabilitation: Assistive Technology, 2*(1), 1-8. doi: 10.1080/17483100600845414

Tutton, M. (2009, November 6). The artificial hand that can 'feel'. CNN. Retrieved from http://www.cnn.com/

Weir, R. F., Troyk, P. R., DeMichele, G., & Kerns, D. (2005). Technical details of the implantable myoelectric sensor (IMES) system for multifunction prosthesis control. *Conference proceedings: Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 7*, 7337-7340. doi: 10.1109/IEMBS.2005.1616206

Ziegler-Graham, K., MacKenzie, E. J., Ephraim, P. L., Travison, T. G., & Brookmeyer, R. (2008). Estimating the prevalence of limb loss in the United States: 2005 to 2050. *Archives of Physical Medicine and Rehabilitation, 89*(3), 422-429. doi: 10.1016/j.apmr.2007.11.005