Executive summary

- The importance of effective human communication in the information age cannot be overstated. In addition to inconvenience, educational disadvantage and loss of economic competitiveness, poor communication leads to social and emotional isolation, cognitive decline and neurodegeneration.
- As the population of developed and, especially, developing countries ages, people will inevitably experience a greater prevalence and degree of hearing loss and associated cognitive difficulties.
- LCH is among the world leaders and founders of an exciting, vibrant and timely new field, cognitive hearing science. HGS builds on this strength, offering a unique programme of multidisciplinary and multicentre training. Training involves research, coursework, seminars and workshops, and encouragement to engage with a variety of outside organizations.
- Just as the standard, quantity and variety of research at LCH is outstanding, so is the quality of the students, the experience and the outcomes produced by HGS. HGS has many strengths, but the bringing together of mentors and students from many backgrounds and age groups, and from both genders, in an environment that is collegial, nurturing, international and inclusive is perhaps the most important.
- We, the independent and international HGS reviewers, recommend that Linköping University provide continuing support for HGS to the level requested, and additional support to enhance the further recruitment and engagement of guest faculty, mobility of the students, and the development of technology to promote distance learning and communication.

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David Moore

Signed (on behalf of the reviewers):

David Moore

23 July, 2012
**Background**

Effective communication is, perhaps more than any other ability, at the centre of what makes us distinctly human. The loss or compromise of communication is, conversely, a dehumanising disability that can lead to social isolation and cognitive decline. Technology, including hearing aids and cochlear implants, can partially address communication impairment due to loss of hearing. However, communication involves a lot more than good hearing, and hearing devices do not compensate fully for impaired hearing, especially at conversational levels of speech in noisy rooms. To gain maximum benefit, substantial cognitive engagement based on fully functional attention, memory and affective systems is needed. Unfortunately, the same people who have impaired communication, whether through deafness or cognitive impairments, are also often those least able to benefit from such devices. For the last 20 years or so there has been an increasing realisation that the cognitive and sensory aspects of human perception are inextricably linked. Those who lack cognitive resources are thus most impaired by hearing loss, leading to further cognitive decline. In the extreme, it has recently been shown (Lin et al., Neurology, 2010) that hearing loss can result in a 5-fold increase in dementia.

The team running the LCH programme at Linköping University (LiU), including the LCH graduate school (HGS), are international leaders in developing, building-on and translating the link between hearing and cognition. Under the leadership of Professor Jerker Rönnberg (LCH) and Associate Professor Mary Rudner (HGS), the team have established an internationally unique, cutting edge, and timely graduate programme that is inter-disciplinary, inter-sectoral, translational and, above all, intellectually outstanding. Development of the next generation of world-leading researchers in communication and hearing science, areas of critical and increasing importance but chronic under-investment, is a goal to which LiU and its LCH partners have established a vision on which they are now delivering.

HGS currently has 36 students enrolled, predominantly from LiU and Örebro University (OU), with small numbers from Göteborg, Jönköping, Lund, Macquarie and Trondheim Universities and the Karolinska. The students come from a wide variety of backgrounds, with psychology and audiology the most common. This number of students, one of the largest of any graduate programme in hearing research in the world, and its mixed composition pose a number of scientific opportunities and logistic challenges. Similarly, the training courses and mentoring opportunities are numerous and diverse, as is the composition and geographical dispersal of the faculty. Together, these conditions provide an exhilarating environment that depends critically on the dedication and flexibility of students and staff and on the provision of adequate resources.

**Mandate and materials reviewed**

The Board of the Swedish Institute for Disability Research (SIDR), under which umbrella LCH lies, commissioned an independent review of the quality of HGS following the end of an initial period of 5 years funding from the Swedish Research Council (VR). This review would serve as a basis for a decision by the Rektor of LiU on continued funding of HGS, in light of continuing funding of LCH for a further period of at least 5 years. The Reviewers were asked to provide, from an international perspective, a report on the School’s achievements and current activities, and recommendations for how activities might continue and be developed further. They were, in turn, provided with substantial written detail on most aspects of HGS including a 6 page report on activities from 2008-
2012, a proposal for continuation for 2013-2017, a 46 page application from HGS to the EU Marie Curie scheme for funding for 4 doctoral students as part of a new mobility programme, four PhD and one licentiate theses, and course and steering committee notes. Additional material reviewed included a 2010 progress report of LCH and the initial EU review of the Marie Curie proposal. In addition, the Reviewers came to Linköping for a 2 day site visit in late May 2012 to interview management and students.

Overview and evaluation of Linneaus Centre HEAD (LCH)

LCH takes a multi-centre and multi-disciplinary approach to the study of hearing and deafness, with a specific and novel focus on the cognitive contribution to hearing. There is a core group of researchers, based mainly at LiU and ÖU, with additional ‘guest’ researchers from Canada and the Netherlands. LCH has very strong leadership that goes to the top levels of LiU, with Bengt Westerberg chair of both the LiU and SIDR governing boards, and Jerker Rönberg the director of both SIDR and LCH. LCH makes up about 50%, and is by far the largest component of SIDR. Hearing research is thus a major component of LiU’s research strength, as highlighted in the LCH 2010 progress report. While this potential was clearly recognised when LCH was established in 2008, its realisation was strongly endorsed in the 2010 review by VR that saw LCH funding increased by 20%, one of only two Linneaus Centres across Sweden to receive this level of added support. LCH has a steering group that meets 3-4 times per year and makes strategic research decisions concerning personnel, budget, new projects, and international collaborations. A core group, the original 2008 applicants and some newly associated members, meets 1-2 times per semester to discuss specific research projects. Finally, an international advisory board meets about annually to advise on science and management.

The LCH scientific programme currently consists of 22 projects organized into 6 clusters. The research is model driven and the main model focuses on ease of language understanding based on individual differences in extraction of speech sounds (based on input, processing speed and working memory) and comparison with long term memory for speech sounds. The model is also applicable to sign language and accommodates multimodal language input. This general model is examined using a variety of different research levels (neural, cognitive, linguistic), interventions (cochlear implants, hearing aids, bone-anchored hearing aids), disabilities (degrees of hearing loss, syndromes, tinnitus), ages, communication modes (speech, sign) and brain monitoring tools (fMRI, EEG, eye movements). Substantial external funding, additional to the LCH grant, has been obtained to study other aspects of hearing and deafness (e.g. online delivery of screening, delivery of cognitive testing).

There are many result highlights. A primary focus is on detailed dissection of the cognitive contributions to hearing, particularly of memory systems, in the context of speech hearing and intelligibility, and underlying brain systems. A second productive area involves outcomes of cochlear implantation in children, focussing on age at implantation and comparison with hearing children. Thirdly, there is quite a lot of work on the mechanisms of sign language in deaf people. These latter areas tie into the primary area through their use of cognitive processing as a common currency of ability. A specific and unique scientific strength of LCH is their expertise in cognitive psychology. Several other institutions, internationally, are interested in cognitive contributions to hearing. But a problem is that, typically, they understand much more about hearing than they do about cognitive
science. At LCH understanding of these two crucial areas is much more balanced, with strength in traditional hearing research, and world leadership (perhaps sharing with the University of Indiana) in cognitive hearing research. A surprise was that there was that there seemed to be little emphasis on behavioural rehabilitation, given the strengths of LCH and current research excitement over the positive results obtained with cognitive training programmes.

In just 4 years, LCH has achieved a phenomenal amount. As above, they have established a reputation as an international leader in cognitive hearing research, a reputation that was crowned by the extremely successful First International Conference in that discipline, held at LiU in June 2011. But this meeting was the culmination of an organizational, intellectual and promotional onslaught on the community by LCH, leading to an accelerated recognition. Highlights and unique features of this onslaught were (i) strategic appointments of eminent foreign authorities into ‘guest’ faculty (notably Johnsrude and Pichora-Fuller), leading to development of complementary strength and direct representation at key international institutions, (ii) a central and intellectually novel tenet, that cognition underlies the most applicable aspects of hearing and deafness, and (iii) widespread publicity of LCH and its mission, including engagement and commitment from world leaders. Underpinning and validating this strategy has been a model-led and hypothesis-driven set of research projects that address key aspects of the interaction between auditory sensation and the brain’s memory systems.

Academic institutions, clinical services and hearing device manufacturers have been quick to embrace these strategies and concepts. For example, at the recent meeting of the American Academy of Audiology (Boston, March 2012), ‘cognitive hearing’ was almost the theme of the meeting. In particular, there was a very well attended and designated session on cognitive aspects of amplification at which a LCH faculty member (Thomas Lunner) presented research on some cognitive aspects of hearing aid use, contributing to the research base to a growing recognition that this approach is THE way forward in further development of hearing aid and cochlear implant intervention.

The publication record of LCH is very strong, considering the short duration of its existence, but unsurprising considering the excellence of the programme and its members. As highlighted in the 2010 report (and on the website), several papers have been published in the best journals in the field (e.g. Journal of Cognitive Neuroscience, Neuroimage), and the level and quality of publications is escalating as the programme matures. Other measures of output, aside from the international meeting, have thus far been the organization of inter-institutional workshops, conference presentations, public understanding exercises and the preparation of commissioned reports. These are all worthwhile activities in terms of further developing the staff, students and their research (see below) as well as promoting understanding, translation and profile.

Overview of HEAD graduate school (HGS)

LCH and HGS are administratively independent, but their activities are highly interdependent, particularly in terms of their shared mission – “working for excellence in cognitive hearing science”. HGS was borne out of a training programme, started in 1996, at the Centre for Disability Research (later SIDR) and has grown and diversified into a large, multi-centre and inter-disciplinary School, as described above. Since the formation of HGS in 2008, four students (at March 2012) have received the PhD degree. Most (26/36) HGS students are also enrolled in the SIDR programme, and this
imposes formal training requirements extending to 1.5 years equivalent of full-time study. HGS students enrolled in other faculties typically do less compulsory course work (e.g. just 6 months in health sciences). However, unlike many research training models, all HGS students have already chosen their research areas and main supervisors ahead of initial enrolment. They are therefore already involved with their research projects (from day 1) prior to starting coursework. While their research gradually winds-up and courses wind-down as they proceed through their degrees, coursework and research continue to proceed in parallel most of the time. Total training time is four years, allowing 2.5 years (for a SIDR PhD) to complete individual research projects. However, many students are engaged in teaching (20% of time), extending candidature to 5 years, and some have part-time jobs that can take them to an 8 year PhD.

All students have a supervisory team, consisting of the main supervisor and at least one other with complementary skills and interests. The students underlined the advantage of accessibility to professors with different professional background and the willingness of those professors to answer questions when desired. Students also have an individual study plan that documents individual training requirements (notably courses to be taken) and their fulfilment. This is reviewed every 6 months by the supervisory team. Halfway through their research project they must make a presentation, and this provides a valuable reality check. Finally, HGS has a steering group (chaired by Rudner), to oversee operations and strategy, and shares an external advisory board with LCH.

The core of formal training for all SIDR PhD students is the foundation course in disability research, accounting for 25% of overall course work. This provides a theoretical overview of disability that emphasises the importance of multidisciplinary understanding and approaches. It also adopts a ‘vertical’ approach that emphasises different levels of explanation (e.g. neural, cognitive, medical, social). A second compulsory component of SIDR training is a Philosophy of Science course that uses disability research as a model. The remaining 70% of coursework is made up of individually chosen training modules, including several organised by LCH (neuroimaging, advanced statistics, hearing and deafness research) and specifically geared towards the needs of HGS students. It is important to note that these courses are not offered anywhere else. Another core HGS activity is the biannual workshops (one a residential summer workshop and one at the Karolinska Institute) at which students present and discuss their work, and network with scientists, students and other stakeholders from elsewhere in Sweden. Attendance at LCH seminars is expected of all HGS students and, indeed, the students formally organise and participate in the seminars.

Evaluation of HGS

HGS has attracted very favourable evaluations, for example from the 2010 international review of LCH. From the published materials we viewed, particularly the PhD theses, we also developed a very favourable impression of the quality, scope and focus of the HGS students and their training. Much of the research is unconventional in that it is highly applied, and yet strongly driven by high level theoretical principles. At the same time, the range and quality of experimental science is impressive. Our experience during the site visit was equally favourable. Eight of the students gave short presentations on their research. These talks highlighted the variety of research topics (from signal transduction in the ear to theory of mind in deaf-blindness), the different backgrounds and outlooks of the students (e.g. an 18 year experienced speech/language pathologist from Uppsala now based at LiU but collaborating in Stockholm and wanting to develop home-based interventions to improve
speech perception), the emphasis on applied research and disability, and the shared interests and collegiality. For example, the benefit of using baseline data gathered by other students was underlined, an obvious advantage where students might otherwise compete for the same, relatively small pool of potential child experimental participants who could only be expected to sit through limited testing.

Our informal discussions with the students were very illuminating and also generally very positive. Strong objective support is that very few students have ever left the course. They were an obviously very bright, enthusiastic and personable group of young (and not so young) scientists. We were impressed by the variety of their academic backgrounds and experience, both in terms of quality and quantity. Some were relatively recently out of undergraduate degree courses and they were typical of the gifted, brash and optimistic types that we have all experienced among our more talented young students. But they had an obvious passion that indicated the extent to which they were thinking hard about and were committed to what they were doing. Several of the students had spent many years in work, mostly in clinical practice, prior to starting their doctorate. Some of these people thought the course unreservedly wonderful, and particularly liked the unique way in which both SIDR and LCH worked. Others were more opinionated and reflected concerns about isolation, relevance and flexibility that is not uncommon among older students. Some of these people had been doing their degree for a long time, due to part-time continuing clinical work, and we had the impression they might find the balance between the two (and, presumably, their private life) very difficult to sustain over many years. Nevertheless, like all the students, there was a sense of drive that was amplified by the desire to see good coming out of their work. There is no doubt the students were united in being driven by a sense of the importance of what they were doing, or might do for disabled people.

Without actually experiencing any of the course work content, and therefore being unable to comment authoritatively on it, we felt that the course work requirements and organisation were an area in which improvements could be made. The SIDR foundation course, while being well-liked by some, was also seen as being too ‘long’, too ‘irrelevant’, or too ‘soft’ and was, in short, a distraction from the real business at hand. It has to be said, however, that the minority were even more vocal in their support, citing the obvious fact that they had enrolled in a SIDR-based degree and so expected to cover broader topics in disability research. The LCH courses were much more well received, as were the workshops and seminars. Those who had actually experienced the ‘introductory’ course on ‘hearing and deafness research’ were very enthusiastic, but it turned out that only 2 or 3 of 8 students had actually had a chance to experience that course. Other courses, delivered by the guest faculty, were even more popular, but they were essentially one-off events rather than actual, regular courses. Thematic workshops were seen by some as preferable to more eclectic sets of presentations but, as with all things, not everyone agreed. The Karolinska workshops were very popular, and we got the impression the students liked those because they had a level of scientific gravitas that some of the other course may have lacked. In sum, this is an area where work could be done and where internet and other digital-based technology could help. Trying to organise some core HGS courses (either ‘real’ or ‘virtual’) on a regular basis would also be a welcome development. Student activity sheets, supplied to us on request (see below) tended to confirm a somewhat casual attitude to course work.
It has been more difficult to get a generalised sense of how successful the most important aspect, the research project element, of HGS activities has been. As mentioned briefly above, the theses and research presentations we saw were really excellent, and they, together with the number and quality of research publications, are the ultimate arbiters of excellence in a graduate programme. We requested a list of graduate student activity, essentially a summary of the students’ individual study plans summarizing courses taken, scientific production and outreach activities. What was most striking about this document was the number of publications that most students had achieved by completion or soon afterwards. One student, due to finish in 2013, has published no fewer than 8 peer reviewed papers, several others have published 5 or more, and most students of longer than two year’s standing have published at least 1 paper. In addition, there were many abstracts from a wide variety of conferences. The networking and dissemination opportunities were obvious. Clearly, productivity and visibility among this group are not issues. However, a slightly closer look suggested that only a small proportion of the papers were in highly regarded, international peer-reviewed journals. This brings the quantity-quality ratio down to something a bit more realistic. Based on our experience, it is very important to have breadth as well as depth in a scientific portfolio, especially when the research is translational, as most of the output of HGS is. On balance, it is desirable to see this research published, even in a journal that may not be the best, rather than remain unpublished and hence representing wasted effort, other than for the development of the individual.

**Resourcing HGS**

As outlined in the HGS report (March 2012), VR will contribute (in 2012) nearly 2.5 SEKm towards support of HGS. Unfortunately, that source of funding will not be available in 2013. The 2010 VR review of LCH recommended that “HGS does not pay salaries for PhD-students but it organises courses, supports visits to other laboratories and conferences. Additional funding is needed for HGS as the requested funding from the Linnaeus grant is beyond the scope of potential fiscal adjustments. However, the panel encourages the steering group to continue to identify other additional resources to run HGS as it is of high value for the centre.” Accordingly, in January 2012, Rudner led a request from HGS to the EU Marie Curie scheme for funding for 4 doctoral students as part of a new mobility programme. Despite receiving very favourable reviews (scoring 86.2/100), we have just (15/6/12) heard that the proposal will not be funded in the present round. In any case, since the Marie Curie scheme would have led to an expansion of HGS, there is still the issue of the missing 2.5 SEKm p.a., inflated over the coming 5 years that marks the lifetime of the current LCH grant.

Our view is that HGS offers exceptional value for money, that it is a leading driver of the work of LCH and, if our recommendations are to be implemented, that it could use some additional funding. Currently, the budget is split more or less into three parts, salaries, travel/workshops and overheads/office space. Two of these parts (salaries, overheads) are fixed elements that must be maintained. We identified travel (both by HGS to other sites and guests to HGS) and workshops as two of the most successful elements of the LCH/HGS organization. Bringing more guests to LIU, maintenance of the workshop programme (or possible expansion of designated theme workshops), and implementation of better communication infrastructure, are all high priorities for the further development of HGS.
Issues, challenges and recommendations

- Continuing plans for mobility and international collaboration that have been highly successful will require careful and sustained management that is resource intensive. Those resources should include expansion of the guest faculty/visitor scheme that has proven so successful in building both LCH and HGS, and expanded and improved ability to use modern communication techniques (internet, teleconferencing, video archiving) to stay in touch with collaborators. Further development of the HGS website will also be required.

- Number and level of research publications is very strong, but could be even stronger. In particular, presenting some key findings in even a small number of higher impact, more generic journal articles would enhance considerably the academic kudos of LCH and the field of cognitive hearing research. Our view is that this could be a matter of ambition and culture rather than quality of the underpinning research.

- Completion rate for PhD students is currently modest. While this is generally understandable in terms of the age of the programme, we identified several instances of students of very long candidature. Part-time and distance (non LiU) students can feel alienated. Improved communication will help, as would tighter management.

- Review the relevance and suitability of the core curriculum of SIDR and consider adopting a more flexible and consistent approach to delivering course work to HGS students. Use of recorded material and generally broader use of internet delivery would keep people in touch and allow greater choice and flexibility.

- Consider further development of HGS courses. These are generally popular, but they are erratic and, in some cases, infrequent. More regular (e.g. annual) courses, especially in the fundamentals of audiology and auditory science, would be desirable. Recording of guest speaker lectures and seminars should be routine. As above, expansion of the guest faculty scheme could result in more, and more regular presentations.

- Perhaps the greatest strength of LCH is the understanding and clever use of cognitive psychology, applied to the focussed issue of hearing and deafness. Building further (including local) strength in complementary areas, particularly cognitive neuroscience and psychoacoustics, would further advance longer-term research objectives.

- Knowledge of disability is necessary to develop suitable interventions. But interventions are necessary to enable improved outcomes. As LCH and HGS mature we suggest that the balance might shift a bit from diagnosis and more towards behavioural rehabilitation. Better still, current interests would be retained and rehabilitation added as a focussed growth area.

- Building on the focus and translational aspects of the training, but the diversity of student interests and backgrounds, even closer links with industry, and a wider variety of industry (e.g. computing, electronics as well as hearing devices) would be desirable.

- It is surprising that HGS does not list capacity building – developing the next generation of researchers – explicitly in its list of goals. This isn’t a particular criticism of the HGS structure, but may be an important cultural aim to clarify.

- The model of recruiting students directly into specific research projects before they even begin their quite extensive coursework is increasingly unusual and questionable. An international standard (‘Bologna’) model of 1(or 2)+3 year Masters/PhD training allows an initial period of mixed formal training and minor research project(s), an important purpose.
of which is to allow students to make a more informed decision about their PhD research project (and supervisor).