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Medical spoken language translation: What do the users really need?

Harold Somers
School of Languages Linguistics and Cultures
University of Manchester
Manchester, UK
harold.somers@manchester.ac.uk

Abstract

This paper focuses on the particular use of spoken language translation (SLT) technology in the medical domain, in particular to assist communication between patients with limited English and healthcare providers. The paper points out that the pathway to healthcare for such patients extends beyond the focal point of a doctor-patient dialogue with a GP as it is conventionally portrayed, to include interaction at various stages with a range of medical specialists and non-specialists. The translation needs (both spoken and text) vary accordingly. The paper then critically reviews work done so far on SLT in the medical domain, in particular considering the most appropriate set up - who is the principal user, doctor or patient? - and at some factors in the deployment of multimodal interfaces to support the speech input. Finally the paper discusses whether SLT is really the most appropriate technology, and discuss some of the barriers to implementation, especially considering the fact that in many cases the languages spoken by the kinds of patients we are targeting happen also to be languages of least interest to commercial developers of language technologies.

1 Introduction

In recent years researchers in the field of Machine Translation (MT) have started to focus on the area of **spoken language translation** (SLT), thanks to considerable advances in the contributing fields of **automatic speech recognition** (ASR), and speech synthesis (SS). Recognizing that spontaneous spoken language is significantly different from written language, research has been split between on the one hand purpose-built SLT systems, where the ASR task is coupled with or even replaced by a speech understanding module,[1] which feeds directly into target-language generation, and on the other, systems which operate on the basis of a simpler pipeline architecture, where ASR converts speech to text, conventional MT translates the text, and **text-to-speech** (TTS) synthesis outputs the result. Although the former method may be more robust, and makes more sense given the nature of natural spontaneous speech, with its disfluencies, repetitions, hesitations and lack of (or different) grammaticality, there is an overhead in the need nevertheless to model what is to be understood. The alternative of stringing together now well established technologies (ASR, MT, TTS) is very attractive, especially for the particular task, overwhelmingly the most common in SLT research, of **cooperative**

[1] In ASR the goal is to transcribe (as text) what was said; the aim of speech understanding is to respond appropriately to the spoken input. Perhaps surprisingly, the latter task is easier, since the requirement to analyse every part of the speech signal accurately is reduced.

task-oriented dialogues. A particular example of this, where there is a clear real-world problem that cannot be solved using traditional human resources alone, is in the medical setting, translating between doctors (or more generally, healthcare providers) and patients (healthcare seekers) with limited proficiency in the dominant language.

This paper will attempt to survey the latest research in this particular neck of the SLT wood, but somewhat critically, since the present author believes that some of this research would benefit from being more **user-oriented,** and less driven by the available technology. To make the point, we will first look at the "pathway to healthcare" for such patients in that it extends beyond the focal point of a doctor-patient dialogue with a GP as it is conventionally portrayed, to include interaction at various stages with a range of medical specialists and non-specialists, with translation needs (both spoken and text) varying accordingly. At the same time, we will consider possible language technologies that can play a role at each step. We will then critically review work done so far on SLT in the medical domain, in particular for its bias towards the doctor as the principle user of proposed software, and its often condescending view of the patient's role. Finally, considering the fact that in many cases the languages spoken by the kinds of patients we are targeting happen also to be languages of least interest to commercial developers of language technologies, we will discuss some of the barriers to implementation, and suggest some ways around them.

2 Patients with limited English proficiency and the pathway to healthcare

In the UK and elsewhere today there are recent or long-term immigrants, refugees, and asylum seekers and other people whose command of English[2] is inadequate for more formal situations such as interactions with health services, especially visits to their doctor. There is no shortage of literature reporting disparities in healthcare provision in these communities where communication difficulties are identified as the single most important factor (e.g. Jones & Gill 1998, Fassil 2000, Jacobs et al. 2001, Bischoff et al. 2003, Flores et al. 2005, Westberg & Sorensen 2005).

An equally rich literature discusses traditional ways and problems of addressing this problem, through use of interpreters and other services, of which we can only give a flavour here. Trained professional interpreters or community advocates may seem to offer the best solution but in reality these services are often unavailable, too expensive or unable to cover all languages required, particularly in emergencies (Jones & Gill 1998, von Kaehne 2002, Karliner et al. 2004). Untrained bilingual staff are often enlisted to help out at short notice, or an expensive 24-hour telephone interpreting service may be accessed, requiring hands-free equipment. Without any of the above, patients and providers just have to "muddle through" or, as often happens, abandon the consultation. Providers often resort to the use of untrained family or volunteers to act as interpreters, which can lead to lack of impartiality, breaches of confidentiality and inaccurate, misleading translations.

[2] For convenience in this paper we use the phrase “patients with limited English proficiency (LEP)”, though it should be understood of course that much of the discussion would apply equally to other countries where the host or majority language is another language.

While it is natural to focus on the doctor-patient consultation as the central element of the pathway to healthcare, in fact, this is only one of many diverse interactions that a patient has with a variety of healthcare providers, including receptionists at clinics and hospitals, paramedics, nurses, therapists, pharmacists as well, of course, as the "doctor" who may be a GP, a consultant, a specialist, and so on. Each of these interactions involves a range of communicative activities requiring different language skills, often but not inevitably involving translation in some form. Accordingly, different language technologies are also implied.

The pathway might begin with a person suspecting that there may be something wrong with them. Many people nowadays would in this situation first try to find out something about their condition on their own, typically on the Word-Wide Web. If you need this information in your own language, technologies implied are **multilingual information extraction** and MT perhaps coupled with text simplification. In addition, if you have limited literacy skills, synthesized speech output would be helpful. For specific conditions which may be treated at specialist clinics it may be possible to identify a series of frequently asked questions and set up a pre-consultation **computer-mediated help-desk** and interview (cf. Osman et al. 1994).

Having decided that a visit to the doctor is indicated, the next step is to make an appointment. **Appointment scheduling** is the classical application of SLT, as seen in most of the early work in the field, and is a typical case of a task-oriented cooperative dialogue. A good example is the Verbmobil project (see Wahlster 2000), in which a dialogue “model” was an important component (Kipp et al. 2000). Note that the dialogue partner – the receptionist in the clinic – does not necessarily have any medical expertise, nor possibly the high level of education and openness to new technology that is often assumed in the literature on SLT.

If this is the patient's first encounter with this particular healthcare institution, they may wish to get their "history", a task nowadays often done separately from the main doctor-patient consultation, to save the doctor's time. This might be a suitable application for **computer-based interviewing** (cf. Bachman 2003).

The next step might be the doctor-patient consultation itself, which has been the focus of much attention. While some developers (e.g. Bouillon et al. 2005) originally assumed that the patient's role in this can be reduced to simple responses involving yes/no responses, gestures and perhaps a limited vocabulary of simple answers, current clinical theory in contrast focuses on **patient-centred medicine** (cf. Stewart et al. 2003), an issue mentioned for example by Bouillon et al. (2007). The session will see the doctor eliciting information in order to make a diagnosis as foreseen, but also explaining the condition and the treatment, exploring the patient's feelings about the situation, and inviting the patient to ask questions. So the dialogue is very much a two-way interaction. Of course this presents massive difficulties for SLT system design.

After the initial consultation, the next step may involve a trip to the pharmacist to get some drugs or equipment. Apart from the human interaction, the drugs (or whatever) will include written instructions and information: frequency and amount of use, contraindications, warnings and so on. This is an obvious application for **controlled language MT,** the feasibility of which has of course classically been demonstrated by Meteo (Kittredge & Lehrberger 1982): drug dose instructions are of the same order of complexity as weather bulletins, though there remains the practical problem of transferring the text from the packet to the translation system. The obvious solution is to have the labels translated at source, i.e. by the pharmacist, though this involves huge problems related to the pharmacist's legal obligation to verify the instructions on the label, which obviously they cannot do if they are written in a foreign language. There is some evidence of use of MT (e.g. Sharif et al. 2006, Barclay 2007, Bradshaw et al. 2007) where available, which of course always needs to be checked for translation accuracy, but this is not a viable solution for many of the languages needed. For non-literate patients, "talking pill boxes" are already available (marketed by MedivoxRx, see Orlovsky 2005), so it would be nice if they could "talk" in a variety of languages.

Another outcome might involve another practitioner - a nurse or a therapist - and a series of meetings where the condition may be treated or managed. Apart from more scheduling, this will almost certainly involve explanations and demonstrations by the practitioner, and typically also elicitation of further information from the patient. Hospital treatment would involve interaction with a wide range of staff, again not all medical experts.

All this introduces the question of who is the principle user of a communication device, which will have a bearing on many design issues. We will consider to this questioning the next section.

3 Spoken language translation in the medical domain

Research on SLT specifically applied to the medical domain has reached a volume sufficient to merit dedicated workshops at conferences. However, almost all the work so far published can be criticised for designs which are biased to just one of the two users (the doctor), and which make unjustified assumptions about the user profiles, in contrast with widely held views in the medical world on patient-centeredness as an essential approach to doctor-patient communication. A major criticism is that SLT development is technology-led when it should be more receptive to the - quite varied - needs of its principle users. It can even be argued that translation, particularly SLT, may not even be the most appropriate technology for certain needs.

Although we cannot be certain to have covered the field exhaustively, based on an extensive literature review, we hope that the following paragraphs include all the major systems developed so far. Table 1 lists medical SLT systems known to this author, giving in each case a most recent reference or website.[3] As far as we can tell, all the systems listed are genuine speech translation systems (rather than speech-activated phrase-books, such as VoxTec's *Phraselator* or Ectaco's *Medical SpeechGuard* for example),[4] though they certainly range from proof-of-concept research projects to fully-fledged systems that are generally available.

It is apparent from the table that the systems can be categorised in a number of ways: the identity of the developers gives some clue as to whether the system is intended for commercial use or is more like basic research. Another distinction is whether the intended use is in the doctor's office or for first contact with medics "in the field", a scenario encouraged by US Defence Agency funding under the CAST programme:[5] the language pairs and domains identify these systems. This distinction mainly

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[3] All URLs were last accessed 23/24 October 2007.
[4] http://www.voxtec.com/p2.aspx; http://www.ectaco.ca/main.jsp?do=products-view_item&item=2743
[5] Formerly known as Babylon. See www.darpa.mil/ipto/ programs/cast/.

motivates differences in hardware, overall design, and coverage, but there may be other more subtle differences that result especially from the situation in which it was envisaged that the CAST systems would be used.

System	Developers	Domains	Languages
CCLINC	MITLincoln Lab (Lee et al. 2002)	doctor-patient dialogue	English, Korean
MASTOR	IBM Yorktown Heights (Zhou et al. 2003)	medical emergencies	English, Mandarin
Speechalator	Carnegie Mellon University (Waibel et al.2003)	medical interviews	English, Arabic
Laser ACTD	Carnegie Mellon University (Schulz et al. 2004)	doctor-patient dialogue	English, Thai
no name	SRI Menlo Park CA (Kathol et al. 2005)	f'irst medical exchanges	English, Pashto
Transonics	University of Southern California (Ettelaie et al. 2005)	doctor-patient dialogue	English, Farsi
Accultran	A-Life Medical Inc, San Diego CA (Heinze et al. 2006)	doctor-patient dialogue	English, Spanish
S-MINDS	Sehda Inc, Mountain View CA (Ehsani et al. 2006)	medical disaster recovery	English, Korean
Converser	Spoken Translation, Berkeley CA www.spokentranslation.com/products/ healthcare	pharmacy, emergency, physical therapy, admissions, ob-gyn, oncology	English, Spanish
MASTOR	IBM Yorktown Heights domino.watson.ibm.com/comm/pr.nsf/ pages/news.20061013_mastor.html	“medical-oriented conversations with members of the Iraqi security forces, in hospital settings and during daily interactions with Iraqi citizens"	English, Arabic (Iraqi and MSA
MedSLT	ISSCO, University of Geneva www.issco.unige.ch/projects/medslt/	headache, chest pain, abdominal pain	English, French Japanese, Finnish Spanish, Greek
S:M|NDS	Fluential Inc, Sunnyvale Ca www.fluentialinc.com/therapy.swf	radiology, physical therapy	English, Spanish

Table 1. Medical speech translation systems

3.1 Users and set ups

Thinking again of the pathway to healthcare, we can raise the question of who is the principle user of the communication device, which will have a bearing on many design issues. Some descriptions of the systems talk of "doctors" and "patients" though others do use more inclusive terms such as "medical professional". Early systems were developed on the assumption that it is the doctor who controls the device: *MedSLT* originally allowed only for the doctor to pose questions, which were answered by a nod or a shake of the head. In the *Transonics* system, it seems to be a design decision,

> There is, however, an asymmetry in the dialogue management in control, given the *desire* for the English-speaking doctor to be *in control* of the device and the primary "director" of the dialog. (Ettelaie et al. 2005:89, emphasis added)

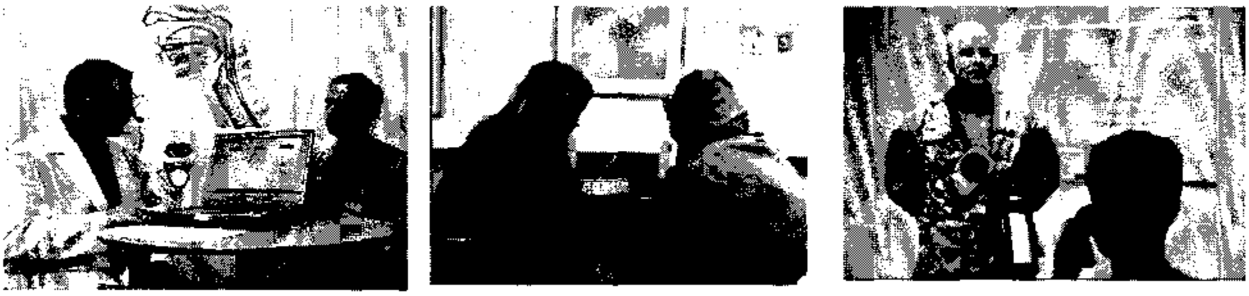
based on the belief that

> the English speaker [...] is expected to have greater technological familiarity (Precoda et al. 2004:9)

so that

> the medical care-giver will maintain the initiative in the dialogue, will have sole access to the controls and display of the translation device, and will operate the push-to-talk controls for both him or herself and the [P]ersian patient. (Narayanan et al. 2004:101)

This set up is illustrated in Figure 1a, taken from an on-line demo of the *Transonics* system. Contrast Figure 1b, showing practitioner and patient sharing a device (in this case not for speech translation), and Figure 1c, the military version of the *S-MINDS* system, illustrating a highly portable wearable device with the non-English speaker using a telephone-like handset. Although the early use of computers in doctor-patient consultations was seen as a threat, more recently the help of computers to increase communication and rapport has begun to be recognised (Mitchell and Sullivan 2001). This may be at the expense of patient-initiated activities however, and many practitioners are suspicious of the negative impact of technology on relationships with patients, especially inasmuch as it increases the perceived power imbalance in the relationship.



(a) Snapshot from *Transonics'* demo movie[6] leaves no doubt that it is the doctor (wearing the white coat) who is in control.

(b) Clinician and patient sharing a laptop device (Somers and Lovel 2007)

(a) The *S-MINDS* system where the main user has the wearable software, while the other user has a telephone handset.[7]

Figure 1. Contrasting perspectives in use of computer-based communication device by clinician and patient

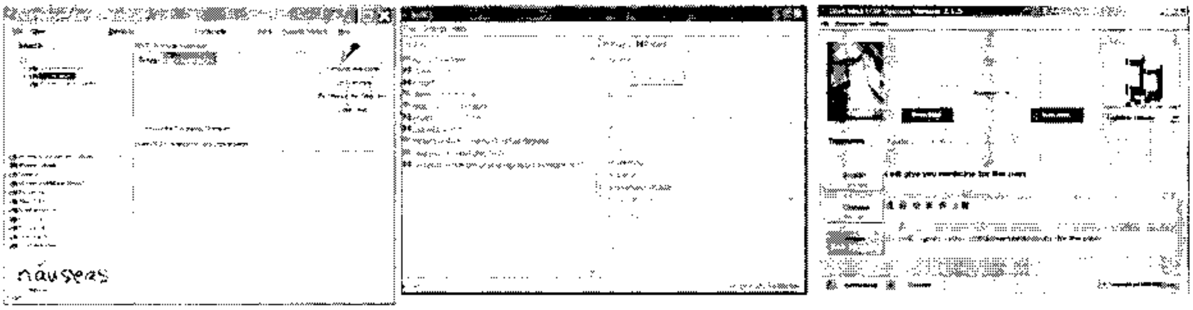
Equipment whose use and "ownership" can be equally shared between the participants goes some way to redressing the perceived power-balance in the consultation. We have evidence of this effect in recently completed experiments comparing (non-speech) communication aids on laptops and tablet PCs: with the laptop, controlled by a mouse or mouse-pad, the practitioner tends to take the initiative, while with the tablet, which comes with a stylus, the patient takes the lead (Somers et al. in press).

3.2 Multimodality

Commonly nowadays, systems take advantage of the additional modalities offered by a graphical interface, where a text trace of what was understood (verbatim transcription and/or paraphrase of the translation to be output) as well as illustrations can reinforce the users' confidence in the system. Figure 2 shows three examples.

Somers and Lovel (2003) assumed that different user interfaces are needed for different users, and these interfaces must accommodate all sorts of users, with or without experience of computers, able or not to type on a keyboard, use a mouse or mousepad, or even to read (Seligman and Dillinger 2006, Somers et al. in press).It is noticeable that the examples in Figure 2 are all highly dependent on text, which may not be appropriate for some users with limited literacy due to visual impairment or lack of education. Incorporating more symbolic graphics into an interface is an area of complexity, as Johnson et al. (2006) report. Iconic text-free symbols, for example to represent "please repeat", or "next question", or abstract concepts such as "very" are not always as instantly understandable as some designers think. Considering the use of symbols form AAC (augmentative and alternative communication) designed for speech-impaired disabled users by non-English speaking patients, we noticed that AAC symbol sets have a systematic iconicity that regular users learn, but which may be opaque to first-time (or one-time) untrained users (Johnson, 2004).

[6] http://sail.usc.edu/transonics/demo/ transedit021r.mov
[7] http://www.youtube.com/watch?v=zNZeFJY53Is
[8] http.//domino.watson.ibm.com/comm/research.nsf/pages/r.uit.innovation.html



(a) *Converser's* input screen showing correction of speech recognition with handwriting (Seligman and Dillinger 2006)

(b) *MedSLT* patient's screen showing possible answers to the most recent question (Bouillon et al. 2007)

(c) The MASTOR system[8]

Figure 2. Examples of on-screen interfaces supporting the spoken language translation

Although research (e.g. by Costantini et al. 2002) suggests that multimodal interfaces are superior to speech-only systems, there are some situations where this will be impractical. Figure 3 shows two more versions of the *S-MINDS* system for use in hospital situations where it is not convenient for either user to access a computer screen, and where the device is necessarily entirely speech-driven.

(a) One-way translation: the patient is not wearing a headset. The system is running on the computer in the background

(b) Both users have headsets; the physician needs to be "hands free". The system is running on the PDA which the therapist is wearing on her belt.

Figure 3. Fluential Inc.'s *S-MINDS* system[9] in two scenarios in which access to a computer screen may not be convenient or appropriate.

4 Discussion

Thus far we have not said anything about the design of medical SLT systems. In the Introduction we briefly contrasted speech understanding and ASR, but in reality almost all medical SLT systems are pipeline architectures, concatenating the three contributing technologies ASR, text MT and SS. While the long-term aim might be to emulate online text translation systems like Babel Fish which "have a go", with more or less success, at translating anything, the reality is that SLT systems, and in particular medical SLT systems, with their critically small safety margins regarding mistranslation, can only function within tightly constrained specific domains in which the range of utterances from both clinician and patient must be strictly limited. This is a restriction which is readily admitted by all developers, and indeed is used as a means of reassuring users of the high quality of translation obtainable.

[9] http://www.youtube.com/watch?v=zNZeFJY53Is

This being the case, one starts to question whether in fact **translation** is the most appropriate road to go down. While earlier apparently dismissing VoxTec's *Phraselator* or Ectaco's *Medical SpeechGuard as* mere speech-activated phrase-books earlier, it is arguable that in fact that is the more reasonable approach to the problem at the moment. Evaluation of pipeline SLT architectures confirms that (conventional) MT is the weakest link in the chain (Somers and Sugita 2003, Lee 2007), so it is clear that the translation function of the system has to take full advantage of what is known and predictable about the things that are going to be said. Similarly, the robustness of ASR is variable: while an input window in which the user can correct the misrecognised utterance seems attractive, in some cases it might be easier to select the input from a drop-down menu of appropriate and likely utterances. These can be associated with prerecorded translations, which would also cut out the processing time-lag noticeable in the demos of even the most polished systems.

Another problem worth mentioning is that the contributing technologies are only available for the relatively small number of the world's "major" languages. It is an inconvenience, but surely not a coincidence, that the groups most badly affected by communication barriers in healthcare speak languages which, for well understood commercial reasons, have not received the attention of computational linguists and language technologists. So even if we wanted to build a pipeline SLT system for, say, Somali or Sylheti or Urdu, we would struggle to find any of the components. The effort required to develop SLT for a new language should not be underestimated (cf. Black et al. 2002, Schultz et al. 2004, Zhou et al. 2004, Narayanan et al. 2004, 2006, Kathol et al. 2005, Besacier et al. 2006, Schultz and Black 2006). The conventional solution lies in a menu-driven phrase-book approach, with prerecorded "translations" of predetermined phrases, though we have explored the possibility of "faking" speech synthesis as an interim solution to this (Evans et al. 2002, Somers et al. 2006) with a fairly promising evaluation based on the doctor-patient dialogue scenario using a German synthesizer to produce fake Somali output. Even more audaciously we have attempted "fake" speech recognition by tricking an English ASR system into recognizing a limited vocabulary of Urdu words, with astonishingly good results when the system has to choose from a set of possible responses (Rizvi 2007). Some of the research in medical SLT can be criticized for being more led by the available technology than by any study of what users really need - what can we achieve given the state of the art in ASR, MT, SS? It is very natural to imagine that the optimal solution would be to provide a system which sits almost unseen in the background translating whatever is said, so that both participants do not even notice that they are speaking different languages. But even if the technology permitted this, it is an unrealistic and inappropriate target. Consultations where a highly trained experienced interpreter performs this task do not meet this description, so why should it be the case when using technology? Any interpreter will quickly agree that translating, particularly in a medical setting, involves much more than conveying the meaning of what is said: all sorts of differing cultural and social norms have to be factored in, and the distinction between "interpreting" and "translating" is surely more than just a matter of modality (spoken vs. written).

References

Bachman JW (2003) The patient-computer interview: a neglected tool that can aid the clinician. *Mayo Clinic Proceedings* 78, 67-78.

Barclay L (2007) Pharmacies may not always translate prescription labels for non-English speaking patients. [Report on presentation by L Weiss at Society for General Internal Medicine 2007 Annual Meeting, Toronto, Ont. Abstract 172022]. *Medscape Medical News,* April 27, 2007. Available at: http://www.medscape.com/viewarticle/555840.

Besacier L, V-B Le, C Boitet and V Berment (2006) ASR and translation for under-resourced languages. In *IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP),* Toulouse, France, V-1221-4

Bischoff A, PA Bovier, R Isah, G Francoise, E Ariel and L Louis (2003) Language barriers between nurses and asylum seekers: their impact on symptom reporting and referral. *Social Science in Medicine* 57:503-12.

Black AW, RD Brown, RF Frederking, R Singh, J Moody and E Steinbrecher (2002) TONGUES: Rapid development of a speech-to-speech translation system. In *Proceedings of HLT 2002: Second International Conference on Human Language Technology Research,* San Diego, CA, 183-6.

Bouillon P, G Flores, M Starlander, N Chatzichrisafis, M Santaholma, N Tsourakis, M Rayner and BA Hockey (2007) A bidirectional grammar-based medical speech translator. In *Proceedings of the [ACL] Workshop on Grammar-based Approaches to Spoken Language Processing,* Prague, Czech Republic, 41-48.

Bouillon P, M Rayner, N Chatzichrisafis, BA Hockey, M Santaholma, M Starlander, Y Nakao, K Kanzaki and H Isahara (2005) A generic multi-lingual open source platform for limited-domain medical speech translation. In *Proceedings of the Tenth Conference on European Association of Machine Translation, "Practical applications of machine translation",* Budapest, Hungary, pp. 50-58.

Bradshaw M, S Tomany-Korman and G Flores (2007) Language barriers to prescriptions for patients with limited English proficiency: A survey of pharmacies. *Pediatrics* 120:225-35.

Costantini E, F Pianesi and S Burger (2002) The added value of multimodality in the NESPOLE! speech-to-speech translation system: An experimental study. In *Fourth IEEE International Conference on Multimodal Interfaces (ICMI'02),* Pittsburgh, PA, 235-40.

Ehsani F, J Kimzey, D Master, K Sudre and H Park (2006) Speech to speech translation for medical triage in Korean. In *HLT/NAACL-06 Workshop on Medical Speech Translation,* New York, NY, 17-23.

Ettelaie E, S Gandhe, P Georgiou, R Belvin, K Knight, D Marcu, S Narayanan and D Traum (2005) Transonics: A practical speech-to-speech translator for English-Farsi medical dialogues. In *43rd Annual Meeting of the Association for Computational Linguistics: ACL-05 Interactive Poster and Demonstration Sessions,* Ann Arbor, MI, 89-92.

Evans G, K Polyzoaki and P Blenkhorn (2002) An approach to producing new languages for talking applications for use by blind people. In K Miesenberger, J Klaus, W Zagler (eds) *8th ICCHP, Computers Helping People with Special Needs,* (LNCS 2398), Berlin: Springer Verlag, 575-82.

Fassil Y (2000) Looking after the health of refugees. *British Medical Journal* 321(7252):59.

Flores G, M Abreu and SC Tomany-Korman (2005) Limited English proficiency, primary language at home, and disparities in children's health care: How language barriers are measured matters. *Public Health Report* 120, 418-30.

Heinze DT, A Turchin and V Jagannathan (2006) Automated interpretation of clinical encounters with cultural cues and electronic health record generation. In *HLT/NAACL-06 Workshop on Medical Speech Translation,* New York, NY, 50-52.

Jacobs EA, DS Lauderdale, D Meltzer, JM Shorey, W Levison and R Thisted (2001) Impact of interpreter services on delivery of health care to limited-English-proficient patients. *Journal of General Internal Medicine* 16:468-74.

Johnson MJ (2004) What can we learn from drawing parallels between people who use AAC and people whose first language is not English? *Communication Matters,* 18(2): 15-17.

Johnson MJ, DG Evans and Z Mohamed (2006) A pilot study to investigate alternative communication strategies in provider-patient interaction with Somali refugees. In *Current Perspectives in Healthcare Computing Conference,* Harrogate, England, 97-106.

Jones D and P Gill (1998) Breaking down language barriers, *British Medical Journal* 316(7127): 1476-80.

Karliner LS, EJ Perez-Stable and G Gildengorin (2004) Language divide: the importance of training in the use of interpreters for out patient practice. *Journal of General Internal Medicine* 19:175-83.

Kathol A, K Precoda, D Vergyri, W Wang and S Riehemann (2005) Speech translation for low-resource languages: The case of Pashto. In *Proceedings 9th European Conference on Speech Communication and Technology (Interspeech-2005/Eurospeech),* Lisbon, Portugal, 2273-6.

Kipp M, J Alexandersson, R Engel and N Reithinger (2000) Dialog processing. In Wahlster (2000), 452-65.

Kittredge RI and J Lehrberger (eds) (1982) *Sublanguage: Studies of Language in Restricted Semantic Domains.* Berlin: de Gruyter.

Krauwer S (ed.) (2000) Special issue on Spoken Language Translation. *Machine Translation* 15, Nos 1-2.

Lee HY (2007) Development of Chinese to English speech translation system based on commercial software components. MSc dissertation, School of Informatics, University of Manchester.

Lee Y-S, DJ Sinder and CJ Weinstein (2002) Interlingua-based English-Korean two-way speech translation of doctor-patient dialogues with CCLINC. *Machine Translation* 17:213-43.

Mitchell E and F Sullivan (2001) A descriptive feast but an evaluative famine: Systematic review of published articles on primary care computing during 1980-97. *British Medical Journal* 322:279-82.

Narayanan S, S Ananthakrishnan, R Belvin, E Ettelaie, S Gandhe, S Ganjavi, PG Georgiou, CM Hein, S Kadambe, K Knight, D Marcu, HE Neely, N Srinivasamurthy, D Traum and D Wang (2004) The Transonics spoken dialogue translator: An aid for English-Persian doctor-patient interviews. In T Bickmore (ed.) *Dialogue Systems for Health Communication: Papers from the 2004 Fall Symposium,* Menlo Park, CA: American Association for Artificial Intelligence, 97-103.

Narayanan SS, PG Georgiou, A Sethy, D Wang, M Bulut, S Sundaram, E Ettalaie, S Ananthakrishnan, H Franco, K Precoda, D Vergyri, J Zheng, W Wang, RR Gadde, M Graciarena, V Abrash, M Frandsen and C Richey (2006) Speech recognition engineering issues in speech to speech translation system design for low resource languages and domains. In *IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP),* Toulouse, France, V-1209-12

Ortovsky C (2005) Talking pill bottles let medications speak for themselves. *NurseZone.com* (online magazine). Available at: www.nursezone.com/Job/DevicesandTechnology.asp?articlelDs14396.

Osman L, M Abdalla, J Beattie, S Ross, I Russell, J Friend, J Legge and J Douglas (1994) Reducing hospital admissions through computer supported education for asthma patients. *British Medical Journal* 308, 568-71.

Precoda K, H Franco, A Dost, M Frandsen, J Fry, A Kathol, C Richey, S Riehemann, D Vergyri, J Zheng and C Culy (2004) Limited-domain speech-to-speech translation between English and Pashto. In *HLT-NAACL 2004, Human Language Technology Conference of the North American Chapter of the Association for Computational Linguistics: Demonstrations,* Boston, MA, 9-12.

Rizvi SMA (2007) Urdu automated [speech] recognition system. MSc dissertation, School of Informatics, University of Manchester.

Schultz T, D Alexander, AW Black, K Peterson, S Suebvisai and A Waibel (2004) A Thai speech translation system for medical dialogs. In *HLT-NAACL 2004, Human Language Technology Conference of the North American Chapter of the Association for Computational Linguistics: Demonstrations,* Boston, MA, 34-35.

Schultz T and AW Black (2006) Challenges with rapid adaptation of speech translation systems to new language pairs. In *IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP),* Toulouse, France, V-1213-16.

Seligman M and M Dillinger (2006) Usability issues in an interactive speech-to-speech translation system for healthcare. In *HLT/NAACL-06 Workshop on Medical Speech Translation,* New York, NY, 1-8.

Sharif I, S Lo and PO Ozuah (2006) Availability of Spanish prescription labels. *Journal of Health Care for the Poor and Underserved* 17, 65-69.

Somers H and H Lovel (2003) Computer-based support for patients with limited English. In *Proceedings of the 7th International EAMT Workshop on MT and Other Language Technology Tools,* Budapest, Hungary, 41-49.

Somers HL, A-L Caress, DG Evans, MJ Johnson, HJ Lovel and Z Mohamed (in press) A computer-based aid for communication between patients with limited English and their clinicians, using symbols and digitised speech. To appear in *International Journal of Medical Informatics.*

Somers H, G Evans and Z Mohamed (2006) Developing speech synthesis for under-resourced languages by "faking it": An experiment with Somali. In *5th International Conference on Language Resources and Evaluation,* Genoa, Italy, 2578-81.

Somers HL and HJ Lovel (2007) Can AAC technology facilitate communication for patients with limited English? ESRC Project Final Report, School of Informatics, University of Manchester. Available at http://www.informatics.manchester.ac.uk/~harold/ ESRCfmal.pdf.

Somers, H and Y Sugita (2003) Evaluating commercial spoken language translation software. In *MT Summit IX: Proceedings of the Ninth Machine Translation Summit,* New Orleans, 370-7.

Stewart M, JB Brown, WW Weston, IR McWhinney, CL McWilliam and TR Freeman (2003) *Patient-Centered Medicine: Transforming the Clinical Method* (2nd ed.). Abingdon, Oxon: Radcliffe.

von Kaehne P (2002) Making the best of health advocates and interpreters. Telephone interpreting is not an acceptable solution. *British Medical Journal* 325(7373): 1175.

Wahlster W (ed.) (2000) *Verbmobil: Foundations of Speech-to-Speech Translation.* Berlin: Springer.

Waibel A, A Badran, AW Black, R Frederking, D Gates, A Lavie, L Levin, K Lenzo, L Mayfield Tomokiyo, J Reichert, T Schultz, D Wallace, M Woszczyna and J Zhang (2003) Speechalator: Two-way speech-to-speech translation on a consumer PDA. In *Proceedings of EUROSPEECH 2003, 8th European Conference on Speech Communication and Technology,* Geneva, Switzerland, 369-72.

Westberg SM and TD Sorensen (2005) Pharmacy-related health disparities experienced by non-English-speaking patients: Impact of pharmaceutical care. *Journal of the American Pharmaceutical Association* 45, 48-54.

Zhou B, D Dechelotte and Y Gao (2004) Two-way speech-to-speech translation on handheld devices. In *INTERSPEECH 2004 - ICSLP, 8th International Conference on Spoken Language Processing,* Jeju Island, Korea, 1637-40.