# Older Adults' Comprehension of Speech as Interactive Domestic Alarm System Output: A Field Study

*Lorna Lines & Kate S. Hone*

Department of Information Systems & Computing
Brunel University, Uxbridge
UB8 3PH, UK.
Lorna.Lines@Brunel.ac.uk

## Abstract

A rapidly ageing population has led to the development of Interactive Domestic Alarm Systems (IDASs) to assist older adults with independent living. This research considers the use of speech as IDAS output and the impact the domestic environment may have on older adults' comprehension of speech outputs. This paper introduces IDASs, the benefits of employing speech as a mode of system output and the critical design issue of user comprehension. Extending previous laboratory studies (see Lines & Hone, 2002a, Lines & Hone, 2002b, Lines & Hone, 2002c) a field investigation is reported that considers older adults' comprehension of speech gender and speech type [natural/synthetic] within the domestic environment. The main findings are discussed and future research directions explored.

## 1 Introduction

The aged sector of the UK population is growing rapidly. Population forecasts indicate that by 2031 30% of the UK population will be over the age of 60 (Dunnell, 2000). Local authorities within the UK report concerns about the resources they can provide for older adults, for example, housing and care services (Help the Aged, 2002). An increase in the aged population is likely to create greater demands on these already overburdened services. To reduce this impending impact it is likely that emphasis will focus on assisting older adults in their own home (Dewsbury & Edge, 2000). The use of technology to meet older adults' domestic needs has been promoted as a means to support independent living (for example, van Berlo, 2001; Monk & Baxter, 2002). A promising technological solution to support older adults with living independently for longer in their own homes is in the current development of Interactive Domestic Alarm Systems (IDASs).

The following sections introduce IDAS's and examine the potential of speech as a mode of IDAS output. Design challenges are considered and the critical issue of user comprehension of IDAS speech outputs is discussed. A field study, conducted in the domestic environment, is reported that extends previous laboratory experiments that investigated older adults' comprehension of speech type [natural/synthetic] and speech gender [male/female] (see Lines & Hone, 2002a, Lines & Hone, 2002b, Lines & Hone, 2002c). The main findings of the current investigation are discussed and directions for future research explored.

## 2 Interactive Domestic Alarm Systems (IDASs)

An example of an IDAS is the Millennium Home System, an IDAS currently being developed at Brunel University in the UK. This IDAS operates using sensors, embedded within the fabric of the older adults home, that detect situations of negative consequence for the older adult through changes in the domestic environment. Situations of negative consequence include doors and windows left open, low room temperatures or if the older adult has had a fall. Sensor data is monitored and analysed by a central computer that, upon detection of an alarm state, activates the user interface to alert the user to the alarm state. At this stage it is expected that the user will resolve the alarm state. If the user resolves the alarm successfully the system will resume a 'safe state'. However, if user feedback is not detected the central computer will initiate an alarm call, via a call centre, to an external care agency requesting human assistance. A 'safe' system state will only be resumed when human assistance has been received. IDAS-User interaction is critical for successful alarm state resolution and IDAS functionality. It is likely that older adults will present physical, psychological and sensory declines and that the level of decline experienced will vary between individuals (Gregor, Newell & Zajicek, 2002). To facilitate IDAS-User interaction, the diversity of ability presented by older adults may be accommodated through the use of a multimodal interface. Due to limited research into user interface design for older adults the use of alternative input and output modalities has yet to be explored. Therefore the current research concentrates on the use of speech as a mode of IDAS output.

## 3 Speech as IDAS Output: Benefits

Speech as IDAS output provides a number of benefits when consideration is given to older adults, the domestic operational context and alarm system functionality. For brevity, these benefits are summarised below:

- The majority of older adults will have the ability to understand speech.
- Visually impaired older adults' will be able to access information that would be difficult, if not impossible, to receive via visual displays.
- Speech output can be received while conducting domestic activities that require the attention of the users' hands/eyes.
- Mobility impaired older adults' will not need to accommodate their physical position or location to receive alarm state information.

However, although a promising mode for the presentation of IDAS outputs, the question of how effective speech output is in a real world context, has yet to be addressed. In this paper we consider the effectiveness of speech as a mode of IDAS output in terms of user comprehension.

## 4 Design Challenges

From a human factors perspective a critical design challenge is how to determine the most appropriate type of speech output to be employed as IDAS output. Speech outputs are available in both natural [human] and synthetic formats employing male or female characteristics. However, little is known about the suitability of alternative speech types [natural/synthetic] and speech gender [male/female] to present alarm state information to an aged user group within the domestic environment. One way in which to address the suitability of speech output for this purpose is to investigate the key design issue of the target users' comprehension of alternative speech outputs. In the case of an IDAS, if the older adult does not understand the speech outputs presented they will be unable to resolve the alarm state detected.

Our initial research into the effectiveness of speech as a mode of IDAS output comprised a series of laboratory experiments to determine older adults' comprehension of alternative speech types

[natural/synthetic] and speech gender [male/female] in both noisy and quiet conditions (see Lines & Hone, 2002a, Lines & Hone, 2002b, Lines & Hone, 2002c). To summarise, the results of the comprehension experiments revealed that older adults' appeared to have little difficulty understanding the speech outputs presented in both quiet and noisy conditions. These investigations revealed that the natural female speech output produced, marginally but not significantly, higher comprehension scores than the alternative speech outputs in both quiet and noisy conditions. However, as expected, in the noisy condition comprehension scores were lower for all speech outputs than in the quiet condition. These findings prompted further investigation into the real world application of speech as IDAS output. The following section describes a field study that was designed to determine the effectiveness of alternative speech outputs within the domestic environment. Therefore the current investigation was driven by the following research objectives:

- To investigate older adults' comprehension of speech outputs presented within the domestic environment
- To compare older adults' comprehension of the speech types [natural/synthetic] and speech genders [male/female] presented within the domestic environment.

# 5 Method

A within-subjects factorial (2x2) experimental design was employed. A simple task was devised that presented alternative speech outputs instructing the participant to put one of five shapes, in one of five different colours into one of the rooms in their home. The independent variables comprised speech type [natural/synthetic] and speech gender [male/female]. The dependent variable was the older adults' comprehension of the speech outputs presented. Comprehension was measured by the number of tasks correctly conducted after listening to each speech output once.

## 5.1 Experimental Design

### *5.1.1 Participants*

4 adults' aged 65+ (1 male, 3 female) were recruited from a pool of 'test-pilots' currently participating in pilot technology trials of the Millennium Home (MH) System. Of the total number of 'test-pilots', only four were deemed suitable to participate in the current study based on age, mobility and hearing ability. Employing MH 'test-pilots' ensured that all participants' had a comprehensive understanding of IDAS functionality. All participants spoke English as their first language. Due to the nature of the task each participant was screened for colour blindness. The experiment was conducted within the older adults' own home. These dwellings were apartments comprising a kitchen, living room, bathroom and one or two bedrooms.

### *5.1.2 Speech Materials*

Male and female, UK English, synthetic speech outputs were created using the Laureate™ online demonstration (http://www.htk.co.uk), a concatenated speech synthesiser. The natural male and female voice samples both had Received Pronunciation (RP) accents. The decision to use RP accents was based on the Laureate™ modeling of the RP accent. With all voice samples using the same accent, it was believed that accent would not be a 'between-voice' discriminatory factor.

### *5.1.3 Procedure*

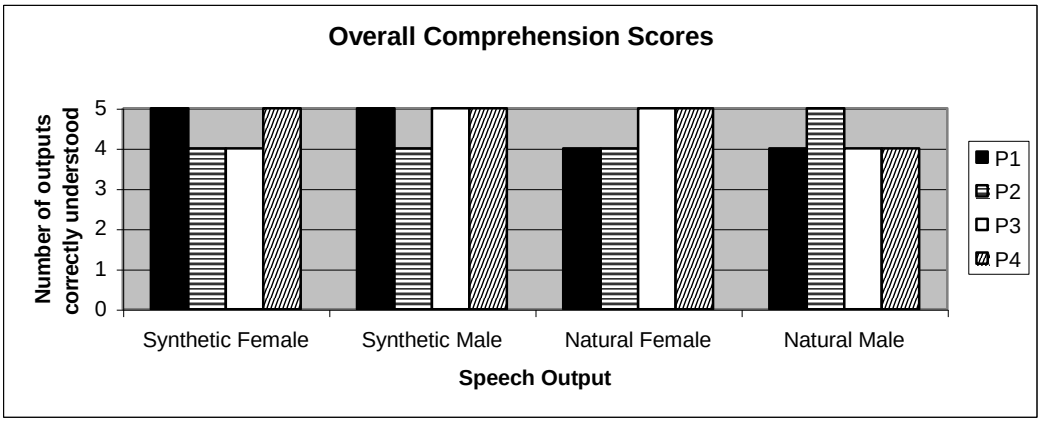
Prior to the trials informed consent was obtained and participants were made aware of their ethical rights. The trials were conducted at the same time on four consecutive days (one speech output type per trial/day, that were counterbalanced to reduce order effects and presented via a laptop and external speakers). At the beginning of each trial the speaker volume was set to a suitable level for each participant. The researcher informed the participant that the task would last 1 hour and that 5

speech outputs would be presented. They were told that each speech output would contain 2 pieces of information. The first denoted the instruction number (the participant was unaware that this was used as an attention grabbing function). The second instructed them to choose one of five shapes [triangle, square, circle, rectangle or star], in one of five different colours [blue, green, purple, yellow & red] and put it in one of the rooms in their home [living room, bathroom, kitchen or bedroom]. Thus each speech output contained three pieces of task information i.e. colour, shape and room. For example "This is message 1. Put the green square in the kitchen". How to repeat a speech output was also explained. The 25 shapes were placed in easy reach of the older adult. When the researcher was satisfied that the older adult understood the comprehension task, the computer program was started and the researcher left the dwelling to return one hour later to calculate the comprehension score for each speech output type presented. Participants' comprehension was measured as the number of speech output instructions that were correctly followed (giving a score out of five for each condition). A more fine grained measure of comprehension was provided by the number of individual pieces of information that were correctly adhered to i.e. colour, shape and room (giving a score out of 15 for each condition). When the researcher had calculated the comprehension score the participant was debriefed and thanked the participant for their cooperation.

# 6 Results

The speech comprehension results are illustrated in figure 1 below. The graph shows the number of tasks successfully completed in each condition for each participant. Together these results show identical levels of performance with the natural and synthetic female speech outputs (18/20 instructions followed correctly). Performance with the synthetic male speech output was marginally better (19/20 instructions correctly followed) and marginally worse with the natural male (17/20 instructions followed correctly). Where comprehension errors were made, these were related to the shape or the colour of the shape, but not the room in which to place the shape.

**Figure 1:** Speech Comprehension Results




# 7 Discussion & Future Directions

The high comprehension scores for each type of speech output [natural/synthetic, male/female] suggest that speech is a promising mode for the presentation of IDAS output. However, due to the small sample size it is difficult to generalise from these results. Rather, observations can be made and future directions for further research can be explored. High comprehension scores for all four speech outputs could be accounted for by the fact that the participants were involved in an

'artificial task' and paid more attention to the speech outputs presented. If speech is to be implemented as a mode of IDAS output, further investigation is necessary to determine the long term effectiveness of the alternative speech outputs. Comprehension errors relating to the semantic and/or syntactic structure is also worthy of further investigation. The results revealed that errors were made based on the shape and the colour of the shape, but not on the room in which to place the shape. In the functional context of an IDAS, comprehension of the room item is likely to lead to the IDAS user identifying an alarm state even when the alarm state information is not fully understood. Alarm states that can be detected by an IDAS are location dependent, for example, a window left open in the kitchen. If the user understands which room the alarm state is active in they may enter the room and actively seek out the alarm state. The lack of errors based on the last piece of information presented, i.e. the room, may reflect either a) that recall is better for room items rather than shape or colour items or b) that a recency effect has occurred whereby participants have only recalled the last piece of information presented, perhaps due to difficulties processing the speech outputs and increases in cognitive demands. In either case, further exploration of the semantic and syntactic structure of IDAS speech output is necessary. Two implications for IDAS design can be identified. The first is that speech outputs appear to be a promising mode for IDAS output and secondly, both the semantic and syntactic structure of IDAS speech output need to be addressed to optimise user comprehension.

## References


Dewsbury, G.A., & Edge, H. M. (2000). Designing the Home to Meet the Needs of Tomorrow...Today: Deconstructing and rebuilding the home for life. *Paper presented at the ENHR 2000 Conference*, June 26-30, Gävle

Dunnell,, K. (2000). Policy Responses to Population Ageing And Population Decline - United Kingdom. *Paper presented at the The Expert Group Meeting On Policy Responses To Population Ageing and Population Decline, Population Division, Department of Economic and Social Affairs, United Nations Secretariat, New York, US.*

Gregor, P., Newell, A. F., & Zajicek, M. (2002). Designing for Dynamic Diversity – interfaces for older people. *In Proceedings of ASSETS 2002, The Fifth International ACM Conference on Assistive Technologies*, 151-1155. July 8-10, Edinburgh, UK.

Help the Aged (2002). Nothing Personal: Rationing Social Care for Older People. Available: http://www.helptheaged.org.uk/Viewpoint/Research/_default.htm.

Lines, L., & Hone, K. S. (2002a). Older Adults' Comprehension of Speech as Interactive Domestic Alarm System Output. *In Proceedings of ECCE 11, The 11th European Conference on Cognitive Ergonomics*, 335-340. Sept 8-11, Catania, Sicily.

Lines, L., & Hone, K. S. (2002b). Older Adults' Evaluation & Comprehension of Speech as Domestic Alarm System Output. *In Proceedings of HCI 2002, Human Computer Interaction – Memorable Yet Invisible*, Vol 2, 94-97. Sept 2-6, London, UK.

Lines, L., & Hone, K. S. (2002c). Older Adults' Evaluations of Speech Output. *In Proceedings of ASSETS 2002, The Fifth International ACM Conference on Assistive Technologies*, 170-177. July 8-10, Edinburgh, UK.

Monk, A., & Baxter, G. (2002). Would you trust a computer to run your home? Dependability issues in smart homes for older adults. *In proceedings of A New Research Agenda for Older Adults: Workshop,* 21-22. HCI 2002, Sept 2-6, London, UK

Smither, J. A. (1983). Short term memory demands in processing synthetic speech by old and young adults. *Behaviour & Information Technology*, 12 (6), 330-335.

van Berlo, A. (2001.) Design Guidelines on Smart Homes. A COST 219bis Guidebook. Available: http://www.stakes.fi/cost219/snarthousing.htm