Final Report: ***Access and Higher Education: Inclusive Online Learning for Deaf Students***

Submitted by Professor Suzanne Graham

A The grant

The initial application for funding was made by Professor Jill Porter, as Principal Investigator. She elected to retire shortly before the outcome of the application was known; Professor Suzanne Graham was therefore proposed as new PI, with the agreement of the Leverhulme Trust.

The total funding allocated was £218,577, originally over 24 months, with a project start date of 1 November 2019, due to finish on 30 October 2021. Because of delays to data collection caused by the Covid-19 pandemic (see Section b), a no-cost extension was requested and granted in May 2021, resulting in a new end-of-project date of 30 April 2022.

Project team members (all based at the University of Reading) were as follows:

Name	**Time allocated to the project**
Professor Suzanne Graham (Principal Investigator)	1 day per week
Professor Richard Mitchell (Co-Investigator)	2 hours per week
Dr Yota Dimitriadi (Co-Investigator)	2 hours per week
Mr Ilan Dweck (Research Assistant)	2.5 days per week till 31/07/2021; 2 days per week thereafter till 31/03/2022
Ms Helen Lansdowne (Research Assistant)	1.5 days per week till 31/07/2021; 2 days per week 1/08/-30/10/2021; 1.5 days per week, 1/11/202-31/03/2022
Dr Paul Grove (Research Assistant)	2.5 days per week, until 30/11/20220
Ms Gail Hickman (Research Assistant)	2.5 days per week, from 01/01/2021-30/10/2021; 2 days per week,

	1/11/2021-31/03/2022
Mr Ken Carter (Consultant)	Ten days over the project

B Objectives:

The original project objectives, as stated in the grant application, were to:

1. Identify optimal conditions for presenting text-based information to support the learning of students in HE; evaluate these conditions across student groups: - deaf/hearing impaired (DHH); students with dyslexia (DYS) and students for whom English is an additional language (terminology later changed to English as a Second or Other Language, L2, as is more usually employed outside of the English school-system).
2. Develop a model for supporting conceptual comprehension of complex text-based information;
3. Establish a platform for developing an agile system that will be responsive to different user needs;
4. Use this evidence base to inform the development of guidance to providers of online learning and other producers of complex text-based information; draw out the implications for access.

C Research activity:

The stated intention in the original proposal was to conduct the research using two existing University of Reading FutureLearn Massive Open Online Courses (MOOCs), one on 'Begin Robotics', the other on Cognitive Behavioural Therapy - CBT. Once the project was underway, it became clear that these consisted of information presented in a number of ways, not just strictly text-based (i.e through written format), but also (and primarily) through video material (i.e. in spoken format, either in the form of voiced Powerpoint demonstrations, or 'talking heads)'. We therefore re-focused the objectives to explore the presentation of complex information through a variety of online methods (visual demonstration, written text, spoken text).

An important further change to the project design was to move from a within-subjects design (where each participant would view the same material twice, in its original format and in a modified format), to a between-subjects design (each participant viewed either the original or the modified version). This change was made because it became clear on examining the MOOC material that there would be a practice effect of viewing the same content twice, threatening the validity of any assessment of learning. We also decided that participants should view both the Robotics and CBT material, rather than just one of these, as they were too dissimilar with respect to cognitive demands to allow participants to view one or the other (as had been the original intention). While the original target sample was 50/50/50 (across the three groups of interest), we aimed for 60/60/60 for the between-subjects design, to allow for 30 participants in each sub-group and hence facilitate more powerful statistical analyses.

The Covid-19 pandemic broke out near the start of the project, which had a very disruptive impact on our data collection, most of which had to be collected online rather than face to face. It was only in the summer of 2021 that we were able to begin some in-person eye-tracking, for a much smaller of participants than had been intended. The online nature of the study, and the challenging circumstances in which universities and students found themselves, meant that it was difficult to recruit participants (many students told us that they did not wish to engage in any more online activity after having had so much of it throughout lockdown periods).

For the purposes of disseminating information about the project and for participant recruitment, we modified the project title to a shorter, catchier acronym, **DEAL (Digital Education Accessible Learning).**

The study followed the 4 phases outlined in the grant application, reproduced briefly here (for reasons of space):

Developmental phase (Nov 2019-May 2020):

- Sections of the Robotics and CBT MOOCs selected
- Collaboration with a user group (two deaf university students, a deaf lecturer, a deaf technical expert, one ESOL student), to examine these materials and consider how we might edit the materials and strengthen their organizational structure and comprehensibility.
- Covid restrictions (whole team working from home from March 2020) limited access to technical solutions to support material modification meaning we had to work with what was possible via Youtube and Microsoft Stream.
- Two sets of materials for both Robotics and CBT created: the original, unmodified format, which we named **MOOC;** a modified version, which we named **DEAL.** More modifications were made to the Robotics materials as these were deemed by the user groups to be the most challenging.
- **DEAL** modifications included (drawing on user group recommendations and the principles of the Cognitive Theory of Multimedia Learning (CTML, Mayer, 2008):
  - adding Advance Organisers (signposts/signals given to students before they undertake an activity to help them structure the information they are about to learn and to direct their attention to key points); pre-viewing explanations of difficult vocabulary using more familiar language as a form of ‘pre-training’ (Mayer, 2008);
  - breaking some of the information down into smaller segments with summaries;
  - simplifying the language, instructions and layout of some learning activities;
  - adding British Sign Language to video clips;
  - drawing participants’ attention to how to modify (slow down, enlarge) video captions.

During this phase we also developed our measurement tools:

Pre-test for each of Robotics and CBT (seven multiple-choice questions in each).

Questionnaire seeking information on participants' degree subject and qualifications in maths, science, and psychology.

Post-test for each of Robotics and CBT: multiple-choice questions (13 for Robotics, 12 for CBT), plus a Likert-type item on participants' self-assessment of their understanding of the content. The internal consistency of the post-tests was assessed through Cronbach's Alpha, giving a low but acceptable level of 0.60 for CBT. Assessment of internal consistency led us to reduce the 13 Robotics items to 11, giving a final CA of.69.

Literacy assessment: two texts and accompanying questions (16 in total), from the 2015 Cambridge English Language Assessment of Advanced English examination, designed for those at the B1/B2 level of the Common European Framework of Reference and which was scored out of 16. When reliability analysis was undertaken, using the first 10 items only gave the most reliable test, Cronbach Alpha = .67.

Usability questionnaire: participants rated, on a 6 point scale, how useful they found: captions; accompanying tasks; sound/audio; visual images; transcript; speaker's face; bullet points/written summaries; text that introduced the video clips. Further closed items also asked participants to rate on a 6-point scale the extent to which they had attended to each of these aspects. There were open questions for qualitative comments, for comments on what would improve participants' experience, and what they had learnt from the materials. These areas were also explored further in a short interview.

Pilot phase (July- October 2020): We piloted all materials with a total of 8 participants; 1 x DHH, 1 x dyslexic and 6 x L2.

Evaluation/ Main Study phase (November 2020-November 2021):

This consisted of two parts: (1) online viewing and task completion; (2) face to face eye-tracking during viewing of online materials.

For both phases, participants were recruited by emailing flyers and information sheets to over 70 universities. Approximately 50 user groups were contacted, the majority directly via social media.

A payment of £10 was offered as an incentive to undertake (1) online viewing and task completion; and £25 for participation in (2), face to face eye-tracking during viewing of online materials.

(1) online viewing and task completion

Participants were randomly allocated to either the MOOC or the DEAL condition, across all three participant groups, giving the following numbers, which, unfortunately, were below the 60/60/60 we had aimed for:

Table 1: Online participants

Condition	**DHH**	**DYS**	**L2**
MOOC	22	10	25
DEAL	21	9	22
Total	43	19	47

Procedures

Participants were sent links to quizzes assessing their proficiency in reading of English and their existing knowledge of Robotics and CBT-related topics.

They then met online in Microsoft Teams with a member of the Project Team and viewed one version of the two sets of online materials. After viewing, they completed quizzes to assess what they had learnt, and a questionnaire and interview to find out what they had focused on while viewing, what they had found helpful and unhelpful. Interviews were recorded using the record function in Teams.

(2) face to face eye-tracking.

Table 2: eye-tracking participants

Condition	**DHH**	**DYS**	**L2**
MOOC	4	4	7
DEAL	5	1	5
Total	9	5	12

A small number of participants viewed the Robotics videos either in the MOOC or DEAL condition while their eye-movements were tracked. They were then shown diagrams of their eye-movements and asked to comment on why they had focused on what they did. They also completed the pre, post and literacy tests.

D. Conclusions and achievements:

Objective 1: Identify optimal conditions for presenting text-based information to support the learning of students in HE; evaluate these conditions across student groups: - deaf/hearing impaired (DHH); students with dyslexia (DYS) and L2 students.

We consider that this objective was mostly met but not entirely.

The first phase of our research helped us identify the challenges that online learning poses for different groups of learners. Our modifications in the DEAL materials were made in response to those challenges, and we sought to examine (1) whether or not DHH students would learn better using materials modified to reduce literacy and cognitive demands; and (2) whether those benefits would extend to L2 students and those with dyslexia.

Our findings in relation to these two questions can be summarised as follows (using bootstrapped statistics throughout, used in view of the small sample size):

There were some emerging benefits for DHH and DYS learners from the DEAL modification, but less so for the L2 learners. Benefits differed across the CBT and Robotics materials.

Using data from the online participants only, we began by assessing the knowledge participants already had of Robotics and CBT-related fields, exploring scores on the pre-tests, as well as their literacy levels and their qualifications in subjects related to the two fields (Maths and Science for Robotics, Psychology for CBT). A key finding here is that DHH learners had significantly lower scores than the other two groups for Maths/Science and Robotics knowledge from the start (Table 3). There were no statistically significant differences between MOOC and DEAL participants, however.

Table 3: Descriptive statistics for pre-test measures, means and (Standard Deviation), and p values for one-way ANOVA

Pre-test measure	**DHH (n = 43)**	**DYS (n = 19)**	**L2 (n = 47)**	***p***
Literacy (out of 10)	6.14 (2.10)	6.74 (2.40)	6.11 (2.56)	.59
Maths/Science qualification (out of 8)	3.12 (1.47)	4.74 (1.85)	5.55 (2.24)	<.001**
Psychology qualification (out of 4)	1.30 (1.34)	1.05 (1.22)	1.30 (1.21)	.74
CBT (out of 7)	2.09	2.32	1.94	.61
Robotics (out of 7)	4.70 (2.29)	8.21 (2.68)	7.32 (3.36)	<.001**

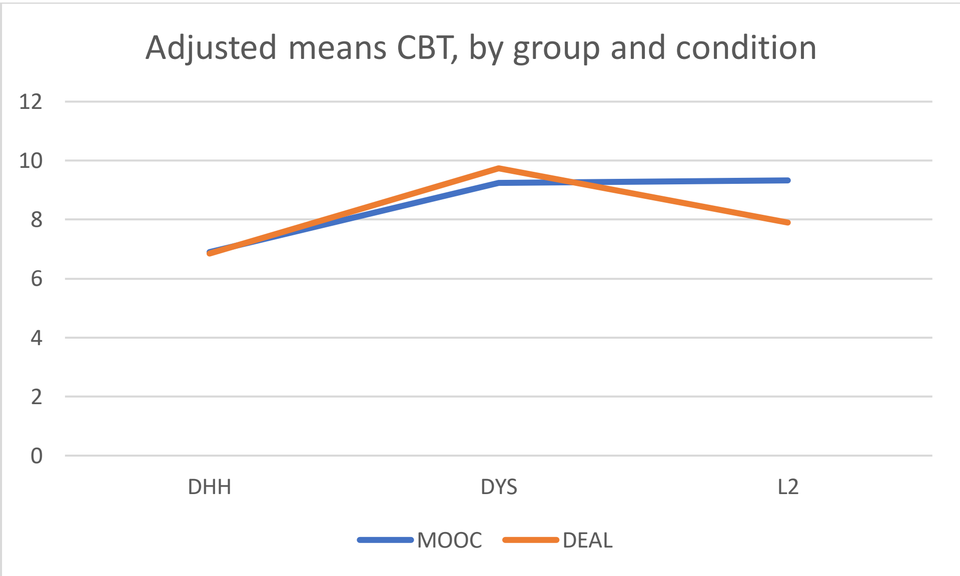
Analyses of post-viewing scores

For each of CBT and Robotics scores we ran a 2 x 3 Analysis of Covariance, with both condition (MOOC, DEAL) and group (DHH, DYS and L2) as fixed factors, and pre-test scores, qualifications and literacy as covariates. Previous analyses had revealed that there was no effect of order, and this was therefore omitted from subsequent analyses.

CBT

Adjusted mean scores (Figure 2) suggested that **the DEAL condition brought some benefits to the DYS participants,** who always performed better than the other two groups but especially in the DEAL condition. It should also be noted that **L2 DEAL participants had lower post-viewing scores than did L2 MOOC participants**

Figure 2



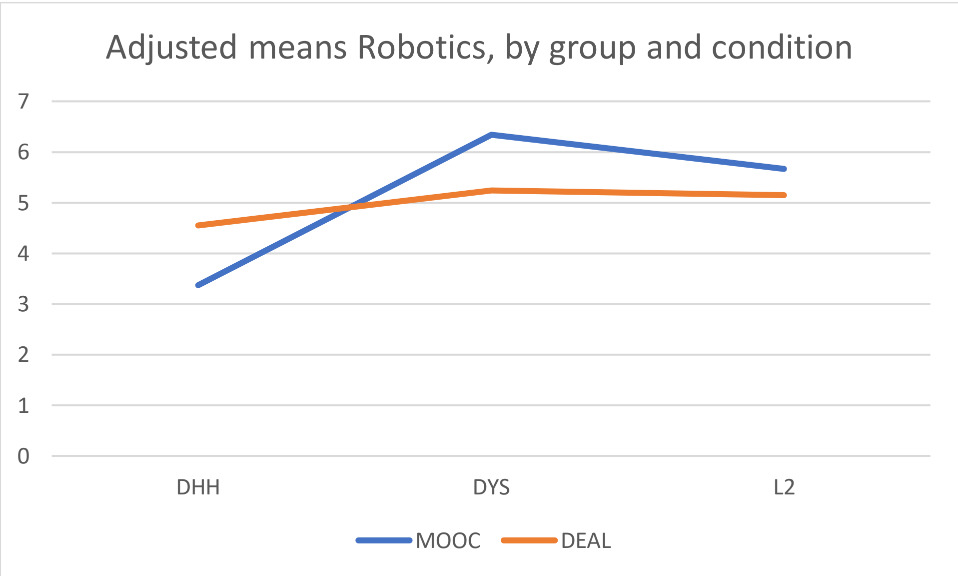
However, the main finding from the ANCOVA was a significant effect of group (F (2, 100) = 1.82, *p* < .001, ηp2 = .20, large effect size – DHH lower than DYS and L2; DYS and L2 did not differ from each other). There was also an effect of literacy (F (1, 100) = 4.77, *p* = .03, ηp2 = .05, small – medium effect size) and psychology-related qualifications (F (1, 100) = 7.87, *p* = .006, ηp2 = .07, medium effect size). In other words, there was no effect of condition (DEAL vs MOOC, F (1, 100) = .56, *p* = .46, ηp2 = .006) nor group * condition interaction (F (2, 100) = 1.82, *p* = .17, ηp2 = .035), meaning we were not able to clearly show a benefit for the DEAL modifications for any group.

Given that DYS learners in particular might be expected to find literacy-based material challenging, and that our initial analysis had detected a significant effect of literacy scores on post-viewing scores, we calculated Pearson correlations between literacy scores and post-viewing scores for the post-viewing quiz for each group and condition separately. For MOOC, the only statistically significant correlation we found was a very strong one for DYS MOOC, r = 77. This had disappeared in the DEAL condition, **suggesting that the DEAL modifications had lessened the literacy demands somewhat for DYS learners.**

Robotics

Adjusted mean scores (Figure 3) suggested that **the DEAL condition brought some emerging benefits, this time to the DHH participants.** When we ran pairwise comparisons for MOOC and DEAL separately, we found that DHH had significantly lower scores than both DYS and L2 only in the MOOC condition. In the DEAL condition, DHH scores did not differ significantly from DYS nor from L2.

Figure 3



This suggests that for Robotics, the DEAL adjustments appear to have had something of an equalising effect on the outcomes for the more cognitively difficult material. This is apparent in Figure 3, where the flatter line for DEAL indicates the more equal performance across the groups.

However, the ANCOVA showed there was a significant effect of group only (F (2, 100) = 4.34, *p* = .016, ηp2 = .08, medium effect size – DHH lower than DYS and L2; DYS and L2 did not differ from each other). In other words, there was no effect of condition (DEAL vs MOOC, F (1, 100) = .086, *p* = .77, ηp2 = .001) nor group * condition interaction (F (2, 100) = 2.10, *p* = .13, ηp2 = .04), meaning we were not able to clearly show a benefit for the DEAL modifications for any group.

Summary of online test data findings

In summary, DHH participants had significantly lower post-viewing scores, except when they viewed the Robotics materials in the DEAL condition. For the CBT materials, literacy levels had a significant effect, which was somewhat modified for DYS learners by the DEAL condition but not for DHH learners; also, L2 participants fared less well when they viewed CBT materials in the DEAL condition. These findings suggest, albeit tentatively, that the modifications made helped DHH learners more in understanding and learning from the Robotics material, which was more demanding on a general cognitive level but not on a literacy level (whereas the opposite was true of the CBT material). However, our statistical analyses were not able to show a clear benefit for the DEAL modifications for any group, possibly because of our small sample size.

Insights from participants

The questionnaire asked online participants how helpful they had found various aspects of the materials. Modified aspects of the materials (accompanying tasks, introductory texts, bullet points/summaries), were rated more highly in the DEAL condition by all three groups and across CBT and Robotics. Differences were however only statistically significant in the case of DYS, and for Accompanying Tasks (CBT) and the Introductory Text (Robotics). It should also be noted that for the majority of materials features, Standard Deviations were fairly large, indicating a lot of variation in what participants found helpful, even within each group. This was also true of our analysis of the eye-tracking data. Standard Deviations were very large when we examined mean percentages of

Total Dwell Time for different Areas of Interest, i.e. individual participants spent very varying proportions of their time attending to different parts of the on-screen presentation.

We ran Spearman correlations between 'helpfulness' scores and post-viewing quiz scores. Interestingly, for DHH there were strong and significant correlations between Robotic post-viewing scores and finding the DEAL introductory text helpful ($r = .693$, $p < .001$). For the CBT materials, viewed by DHH participants in the DEAL condition, there was also a strong and significant correlation between finding accompanying tasks helpful and post-viewing scores ($r =. 647$). Taken together, both of these suggest some emerging benefits from the modifications for DHH learners. We also computed correlations for the DHH group as a whole (MOOC and DEAL combined). For CBT, post-viewing scores were most strongly and significantly correlated with mean positivity scores ($r = .56$), but also with literacy scores ($r = .37$), and prior knowledge ($r =.37$). Furthermore, when these variables were entered into a simple linear regression (with CBT post-viewing scores as the dependent variable), the model as a whole explained a large (68.90%) and significant amount of the variance in CBT scores, and 'perception of helpfulness' emerged as the strongest and only significant predictor (Beta = .49, $t = 4.07$, $p < .001$). The only significant relationship with Robotics post-viewing scores was with finding helpful the text that introduced the video clips, for the DHH sample as a whole, $r = .42$. A regression analysis also revealed it as the only significant predictor of post-viewing scores, (Beta = .41, $t = 2.65$, $p < .001$).

Overall, therefore, an interesting finding is that how helpful learners found specific aspects of the materials presentation reflected how well they could learn from them. In other words, it highlights the importance of personalisation of modifications. That is, modifications are linked with better learning when they meet the needs of individual learners.

Interviews with participants add further insights into the challenges faced by DHH learners, and the extent to which the DEAL modifications helped them or not. For the robotics video materials, DHH participants viewing in the MOOC condition expressed their frustration and difficulty from the demands the materials placed on them, when there were only captions and no BSL. One participant '…found it impossible to look at the visual, read the information and look at the subtitles simultaneously. It was overwhelming and I missed a lot of things'. The DEAL condition, however, seemed for many DHH participants to alleviate the demands of the materials by giving viewers the option of captions and the BSL interpreter. One participant reported having ' the best of two worlds…I could watch the interpreter or the captions'. Some found the BSL interpreter gave them the greatest access: 'I…focused on the signing throughout'. Others found the BSL interpreter enhanced the visuals: ' I think I used a mixture of the on-screen videos and practical demos and the BSL interpreter.'

These views are reflected in an analysis of the features of the materials in each condition that DHH participants found the least helpful (Table 4):

Table 4: Number of times features mentioned by DHH participants as the least helpful aspect

	MOOC	
	Robotics	**CBT**
Speaker's delivery	9	1
Complexity	9	0
Speed	3	0
	DEAL	
Speaker's delivery	2	2
BSL signer	5	4
Complexity	1	0
Speed	3	1

The lower figures for complexity and speed in the DEAL condition provide further evidence that the modifications attenuated the challenging aspects of the materials for DHH learners, especially for the more demanding Robotics material.

By contrast, some DHH participants found the DEAL condition to be a feat of multitasking: 'for me, if there were demonstrations, captions, and the man speaking, it was a lot visually to take in, and it was difficult to know where to focus.' There were also challenges when written text did not exactly match their translation into BSL. One participant explained in more detail why: ' The subtitles and the signing were the same, but some jargon/technical terms were not interpreted into BSL. That's because signs don't exist for most of those terms'. We also noted, in both questionnaire responses and the eye-tracking data, that DHH learners tended to look less at visual clues than the DYS and L2 participants did, especially in the MOOC condition. This was perhaps because there was an overload of visual information in different formats, which to some extent was alleviated by the organisational and structural, simplification modifications made in DEAL. Split attention between captions and transcript, and having to deal with lots of information and new vocabulary at once, all caused difficulties especially in the MOOC condition. This is reflected in the words of one MOOC DHH participant: ' the difficulty was trying to switch between transcript and subtitles and what was being explained. I had to keep pausing and slowing the materials down so I would watch the clip for a while.' This was also the case for some DEAL DHH participants, who found the learning situation overwhelming, even with modifications, with one explaining 'There was a lot of information to take in. I had to really think because I'm not very good at picking up information quickly. My brain is overloaded!'

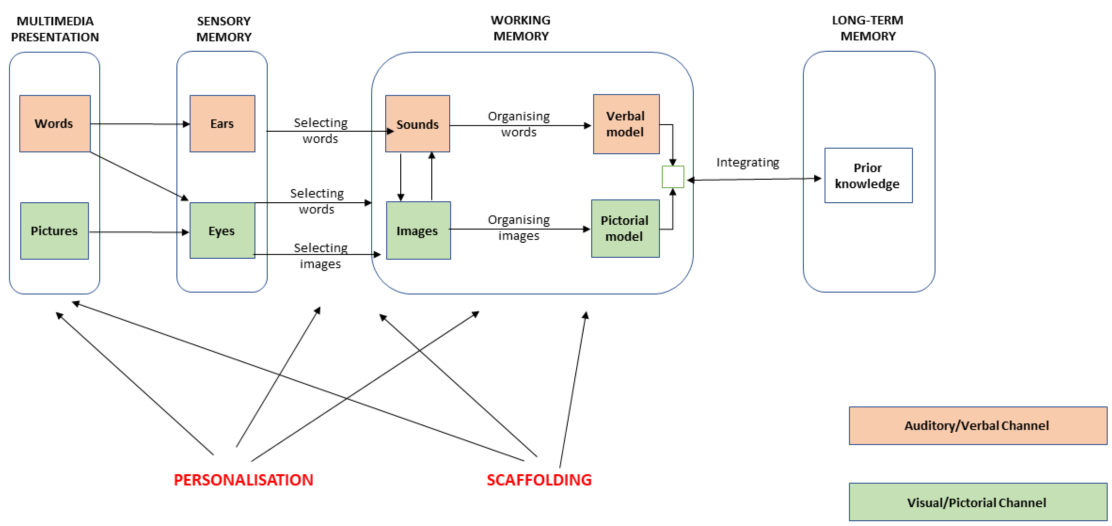
Overall, across and within all three groups, a key theme to emerge was that no modification was universally found helpful. Participants often expressed **a desire to have more control over how they viewed the materials** – for example, repositioning the captions or BSL interpreter. While DEAL participants had been given a help sheet to show them how to make some adjustments (for example, how to slow the speed of the video), they did not often put that advice into practice, and wanted easier and more obvious ways to make such adjustments.

Objective 2: Develop a model for supporting conceptual comprehension of complex text-based information

The attainment of this objective was made difficult by the smaller sample than we had anticipated, which prevented the type of statistical analyses which would ideally have been needed to formulate an entirely new model. Our lack of statistically significant results for Objective 1 also makes model development difficult. Nevertheless, drawing on the findings that we have, and also on qualitative data, we are able to suggest, albeit tentatively, a model of online learning that would address the needs of all three groups together and those of DHH learners specifically. Importantly, this draws on existing models, most notably Mayer's (2008) Cognitive Theory of Multimedia Learning (CTML). Briefly stated, this explains that information presented in words and pictures together, contiguously, is learnt better than through words alone, and that words and pictures are processed through two channels, a verbal and a visual channel. Equally, however, each channel has a limited capacity. Also important is that appropriate, active processing of information accessed in each channel occurs, through 'selecting, organizing, and integrating' (Mayer (2008: 761). The challenge therefore is to find ways of engaging active processing without overwhelming working memory.

Our DEAL modifications, made according to the CTML principles of signalling, segmenting and pre-training and especially for the Robotics material, seemed to have brought benefits to DHH learners; however, the combination of BSL, captions, written text on screen, all primarily accessed through the visual channel, may have prompted cognitive overload, weakening any positive effect of the modifications. By contrast, the same modifications arguably helped DYS participants organize information and rely less on reading of information; their ability to combine aural understanding with clues from visual support, i.e. accessing information through two modalities, seemed to have brought benefits when literacy demands were higher (ie for the CBT materials). Finally, L2 learners seemed to have been challenged in CBT by a relative lack of prior knowledge of the topic which hindered the integration of new information. Their listening comprehension skills were also probably weaker, meaning that they too were less able to draw on information through the aural channel, with the CBT material offering relatively little visual support to compensate. There was also an indication in the interview data that they found the BSL distracting, indicating cognitive overload as was true of the DHH participants.

The CTML implicitly points to the challenges DHH learners in particular will face with multimedia. They are largely obliged to draw on just one channel, the visual, from multiple sources, with the risk of cognitive overload. The answer seems to be to allow personalization of the mode of presentation, to control the input and its positioning/rate of presentation, at the same time as following certain principles drawn from Mayer's CTML. Arguably the CTML does not currently account for learners who can largely use only one channel, or for whom one channel may work less well. A modified version of Mayer's CTML, to be developed fully in the first publication listed in Section F, would likely look as follows, to highlight personalisation and scaffolding at each stage:



Objective 3: Establish a platform for developing an agile system that will be responsive to different user needs

We were not able to meet this objective; by March 2020 the whole research team had to work from home, making access to bespoke and sophisticated technological solutions very challenging. Since the end of the project, however, we have identified new platforms which are partly responsive to different user needs. One such flexible platform is YuJa– see : https://blogs.reading.ac.uk/deal/the-option-of-bsl/

Objective 4: Use this evidence base to inform the development of guidance to providers of online learning and other producers of complex text-based information; draw out the implications for access.

We consider that we have met this objective; our website includes a *Recommendations* page which exemplified modifications that could be made to online learning materials to make them more accessible. See: https://blogs.reading.ac.uk/deal/our-recommendations-2/

We are also working with the University of Reading FutureLearn MOOC team to improve their materials based on our findings.

E. The principal grant holder's personal evaluation of the research project and which elements have been the more successful and which less successful.

Leading a research project of this kind during a global pandemic has been very challenging, especially during periods of national lockdown. Access to research participants has been especially difficult, meaning that our sample size is smaller than we needed to fully meet our objectives. Ideally we would have paused the project during the first national lockdown; however, we were not able to make use of furlough provision for one member of the RA team (for contractual reasons), making this impossible. We were not able to carry out the eye-tracking aspect of the study in the way that was intended. Online eye-tracking has developed greatly over the two years of the pandemic, but was prohibitively expensive at the time we needed it.

By contrast, however, we have achieved a great deal in these challenging circumstances: developing and implementing a range of tests that were used with 109 participants online should be considered a success. We also have qualitative data from these participants which provide rich insights into the difficulties posed by online learning, especially for DHH learners. We were able to form a strong working relationship with our Steering Group, who advised us on materials and on the format of recommendations, including BSL translations and exemplifications.

F. **Publications and other outputs: list actual and prospective publications and other means of disseminating results.**

Three joint articles are in preparation. All project team members will contribute, but each will be led by one of the main investigators, as follows:

Lead author: **Graham, S.** Accessible online learning – what can we draw from the Cognitive Theory of Multimedia Learning? Aimed at the *Journal of Deaf Studies and Deaf Education.*

Lead author: **Dimitriadi, Y.** Inclusive considerations around the use of videos in asynchronous online environments. Aimed at the *Journal of Computer Assisted Learning*

Lead Author: **Mitchell, R.** Learning about Robotics: Design features for different audiences. Aimed at the *International Journal on Teaching and Learning in Higher Education*

G. Future research plans in this field for those involved in the project.

Graham intends to take further the exploration of multimedia learning among learners of a second language.

Reference

Mayer, R.E. (2008). Applying the science of learning: Evidence-based principles for the design of multimedia instruction. *Am Psychol. 63(8):*760-9. doi: 10.1037/0003-066X.63.8.760.