Institution: University of Wolverhampton

Unit of Assessment: 26 Modern Languages and Linguistics

Title of case study: Language Technology to Improve Text Accessibility for People with Autism Spectrum Disorder

Period when the underpinning research was undertaken: 2009 - 2020

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Dr Richard Evans	Lecturer	1998 – Present
Professor Ruslan Mitkov	Professor in Computational Linguistics	1995 – Present
Dr Constantin Orasan	Reader in Computational Linguistics	2001 – 2020
Dr Victoria Yaneva	Lecturer	2016 - Present

Period when the claimed impact occurred: 2015 - 2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact

Research undertaken by the Research Group in Computational Linguistics (RGCL) led to the development of new text simplification guidelines to make texts more accessible for people with autism spectrum disorder (ASD), as well as software to support their implementation by users. This case study focuses on impacts relating to the experiences of service users from three different types of organisations: NHS Foundation Trusts [I1]; non-profit associations providing services for people with ASD [I2]; and a software design and development company [I3]. These impacts occurred as a result of research being used by practitioners/ professionals in conducting their work, influencing professional standards and guidelines, and effecting change in educational practices in higher education (HE) beyond the submitting unit.

2. Underpinning research

Applying Natural Language Processing (NLP) research for societal benefit is one of RGCL's main priorities: by conducting research in close collaboration with organisations, we improve their working methods and help to develop new products. Our researchers are actively involved in knowledge exchange between academia and end-users of research.

People with ASD usually have language deficits with a life-long impact on their psychosocial functioning. In education, only up to 51% of school leavers with ASD achieve GCSE grades A-C with up to 22% transitioning into HE. This compares with 72% and 42%, respectively, for neurotypical school leavers. Up to a third of 16-24 year olds with ASD do not participate in education, employment, or training. This is true of only 17% of neurotypical 16-24 year olds. People with ASD often have reading comprehension deficits that may cause misinterpretation of literal meanings and difficulty in understanding complex instructions. Complex sentences, referential expressions, uncommon or technical words and figures of speech constitute barriers to reading comprehension for people with ASD. In the EU-funded FP7 FIRST project (2011- 2014), RGCL developed a methodology for text simplification and software, which helps intermediaries to implement the associated method when converting texts into a more accessible form for people with ASD. The software, called *OpenBook*, can automatically detect linguistic barriers to reading comprehension in input texts and transform the texts to remove some of these barriers and so make the texts more accessible for autistic individuals.

Since fully automatic text processing is error-prone, the consortium led by RGCL developed an editing tool for carers which enables them to use RGCL's software (NLP technology) to rapidly

adapt texts into a more accessible form for end users. In this way, the changes made to a document are supervised, and the appropriate types of simplification are applied for each user.
Development of the text simplification methodology was one of RGCL's main research foci in the project. A considerable amount of literature on the reading comprehension deficits of people with ASD existed in 2011. However, the development of language technologies to address these issues required a more specific and fine-grained specification of the barriers to reading comprehension faced by this population than was available at that time. RGCL supervised a new detailed user requirements analysis (URA) which specified these barriers and ensured that only the most suitable text simplification components were integrated in the system [R4].

Research findings:
The URA that RGCL supervised included a comprehensive literature review, interviews with end users (carers, educators, healthcare professionals, and people with ASD), and surveys of users' opinions. The URA revealed two main research findings:

F1. Specific linguistic features impede reading comprehension
A set of 46 linguistic obstacles to reading comprehension was derived through our research. Text adaptations were proposed by end users to overcome each obstacle. The obstacles were also classified using a ternary scheme specifying their level of priority (impact).

F2. Provision of assistive linguistic content can make texts more accessible
This included indicative summaries of the content of long documents and illustrative images to improve understanding of specialised terms.

In its research, RGCL focused on F1 and F2. Within category F1, two main types of obstacles were highlighted: obstacles to reading comprehension caused by complex linguistic structure and obstacles caused by ambiguity in meaning. Examples of highly ranked user requirements of categories F1 and F2 are:

Research finding	Obstacle to reading comprehension	Suggested text adaptation	Priority
F1	Long sentences	Provide single clause sentences	High
F1	Phraseological units (idioms, lexicalised metaphors)	Provide simple definitions to explain phraseological units	High
F2	Infrequent words	Support understanding of less common words with images	High

Table 1: Examples of user requirements

Research findings F1 and F2 underpinned development of text simplification guidelines and software components to overcome fourteen of the most highly ranked linguistic barriers. The text simplification guidelines that the consortium developed as a by-product of the URA were presented in Fig 3 of research output [R4]. RGCL's subsequent experiments using eye tracking to investigate autistic reading behaviour led to further refinement of the URA conducted in the FIRST project [R5, R6].

The research underpinning this impact case study includes assessment of the human text simplification process which follows these guidelines and which is supported by use of the OpenBook tool. It was found that intermediaries using OpenBook produced accessible texts in just 60% of the time taken when OpenBook was not used. Furthermore, texts produced using OpenBook were more accessible than those produced without it [R3, R4]. Formal testing of 153 adults and 90 children revealed that autistic reading comprehension of texts simplified on the basis of the guidelines by people using OpenBook was better than their comprehension of the unsimplified texts by a small but statistically significant amount [R3, R4].

In addition to the URA, RGCL participated in a research project on the cognitive processing strategies employed by autistic and neurotypical web users accessing information in web pages [R1, R2]. This study led to a third research finding:

F3. Web pages with fewer elements require less cognitive processing effort for people with ASD and the use of multimedia in web pages requires more
More generally, appropriate visual formatting of documents and software interfaces brings improvements in text accessibility and user experience.

Therefore, software interface developers and web content providers should work to improve the accessibility of textual context rather than supplementing it with multimedia (e.g. video explanations).

3. References to the research

Research outputs R1, R2, R5, and R6 all underwent rigorous peer review. With more than 30 citations each, outputs R2 and R6 show evidence of becoming reference points for further research beyond the original institution. Output R3 underwent monitoring and evaluation by EC experts and ensured the FIRST project's eligibility for the final instalment of funding. Output R4 was derived from peer-reviewed conference papers and project deliverables that also underwent EC monitoring and evaluation.

R1. Eraslan, S., Yesilada, Y., Yaneva, V., and Ha, L. A. (2020) "Keep It Simple!": an Eye-Tracking Study for Exploring Complexity and Distinguishability of Web Pages for People with Autism. *Universal Access in the Information Society (2020), (*https://doi.org/10.1007/s10209-020-00708-9). (Preprint available at: https://bit.ly/3of4mCE).
R2. Eraslan, S., Yaneva, V., Yesilada, Y., and Harper, S. (2019) Web Users with Autism: Eye Tracking Evidence for Differences. *Behaviour & Information Technology*, 38(7): pp. 678-700 (https://doi.org/10.1080/0144929X.2018.1551933) (REF 2 Output).
R3. Jordanova, V., Evans, R., and Cerga Pashoja, A. (2014) *FIRST_D7.8_20141119: Final Evaluation Report*. FIRST Consortium. Can be supplied by the HEI on request. Available at: (http://rgcl.wlv.ac.uk/~richard/Publications/FIRST-D7.8.pdf).
R4. Orăsan, C., Evans, R., and Mitkov, R. (2018) Intelligent Text Processing to Help Readers with Autism. *Intelligent Natural Language Processing: Trends and Applications*, Springer. (https://doi.org/10.1007/978-3-319-67056-0_33) (REF 2 Output).
R5. Yaneva, V. and Evans, R. (2015) Six Good Predictors of Autistic Reading Comprehension. *Proceedings of the International Conference "Recent Advances in Natural Language Processing'2015" (RANLP-2015)*, Hissar, Bulgaria, 7-9 September, pp. 697- 707. (Available at: https://www.aclweb.org/anthology/R15-1089/).
R6. Yaneva, V., Temnikova, I., and Mitkov, R. (2015) Accessible Texts for Autism: An Eye-Tracking Study, ASSETS 2015. *Proceedings of the 17th International ACM SIGACCESS Conference of Computers and Accessibility*. pp. 49-57. (Available at: https://wlv.openrepository.com/handle/2436/609866).

Grants
Mitkov, R. (PI), Orasan, C., Evans, R., Yaneva, V. 'FIRST—A Flexible Interactive Reading Support Tool' - EC Framework Programme 7 - FP7-ICT (approximately GBP1,764,288.66 at 15/09/11, 2011-2014)

4. Details of the impact

This case study presents three impacts arising from the underpinning research. These include changes to the working practices and capabilities of six organisations, which led to improvements in the experiences of their service users. Impact was achieved in three different groups of organisations: two NHS Foundation Trusts [I1], three non-profit associations [I2], and a software design and development company [I3]. These impacts are examples of RGCL's applied research influencing professional standards and guidelines in health and support service delivery and software development.

I1. NHS Foundation Trusts

A major factor behind the successful delivery of clinical services is effective communication with service users. Together, the South London and Maudsley (SLaM) and Central and North West London (CNWL) NHS Foundations Trusts provide mental health services to over 140,000 patients each year. Many of these have learning disabilities (including problems with reading comprehension), making the ability to improve communication with them by converting information leaflets and clinical letters into a more accessible form particularly valuable. The CNWL Foundation Trust was a partner in the FIRST project who helped to pilot the research findings. The text simplification guidelines developed in the project [F1, F2] were implemented by the consultant psychiatrist and her teams at the SLAM and CNWL Foundation Trusts to improve the accessibility of information for their patients. This research-influenced change in professional methods has since had a direct and significant impact on service delivery by improving verbal and written communication with patients [C1].

I2. Non-Profit Associations Providing Services for People with ASD

RGCL's research brought positive changes to the quality of services provided by three associations of this type. These bring improvements in the experiences of service users and will help the associations adapt to changes in cultural values (accessibility and neurodiversity).

Autism-Europe (AE, Belgium) is an international association whose main objective is to advance the rights of autistic people and to help them improve their quality of life. It represents over 5 million people and brings together more than 90 national and regional associations. Research led by RGCL brought new knowledge about the experiences of autistic people with reading comprehension difficulties and about the importance of text accessibility for people with ASD. After the project ended, AE built on this knowledge [F1, F2], dedicating time and resources to develop "easy-to-read" content and webpages for its users and members [C9]. RGCL research helped staff at AE to better meet the needs of the people they work with and advocate for [C2].

Their participation in the FIRST project provided AE with new opportunities for awareness-raising about autism, including opportunities to reach out to a more diverse audience through the production of newsletters and videos and the hosting of dissemination events [C2]. Knowledge gained by AE during the FIRST project enabled them to participate in H2020 projects exploring innovative medicines (AIMS-2-TRIALS) and assistive technologies (DE-ENIGMA), and an EU-funded project investigating prevalence, diagnosis, and interventions to improve care and support of people with ASD (ASDEU) [C2]. This allowed AE to benefit from knowledge exchange and interaction with academics, commercial organisations, and health service providers, further enhancing the expertise underpinning their service provision [C2].

Deletrea SLP (Spain) is a centre for the treatment and diagnosis of people with ASD which includes provision of educational support. Deletrea provides evaluation and diagnostic services to approximately 320 families each year and therapeutic interventions to around 240 people with ASD and their families each month. In the FIRST project, Deletrea benefited from increased knowledge about the reading comprehension of people with ASD, including the international dimension of these issues [C5, C6]. Knowledge acquired through the FIRST project allowed staff at Deletrea to know more precisely which variables can hinder the reading comprehension of people with ASD. This enabled them to rapidly produce accessible content for their users, improving the quality of care provided. Deletrea now provides reading support for people with ASD at a higher quality level than it did before the project began. This includes guidance for parents and carers to improve the accessibility of educational content for their children [C5, C6]. FIRST raised Deletrea's awareness of the potential of assistive technologies to improve service users' abilities to read and study. It now encourages their use of technologies such as *MyStudyBar* and *Detach that book* [C5, C6].

Before the FIRST project began, Parallel World (PW, Bulgaria) was a small organisation serving a user base of seven members. By the end of the project, thanks to its participation in user-focused research activities, PW had increased its user base to 17. Today it stands at more than 80 [C3, C8].

In the project, PW had a key role in interviewing children with ASD and their carers and in running reading comprehension tests of children with ASD. This included the recruitment of participants,

thematic analysis of interviews, and analysis of reading comprehension test results. The increase in PW's know-how, capability, and reputation due to its participation in the FIRST project [C3, C8] paved the way for its subsequent success. The organisation now runs a social enterprise which employs young people with disabilities, currently employs eight full-time employees and eight trainees, and has participated as a lead partner in numerous research projects. These include 15 national (Bulgarian) and international projects funded by programmes such as *Erasmus*, the *Bulgarian Association of Children with Disabilities*, and Bulgaria's *Human Resources Development (HRD)* operational programme [C3, C8].

Prior to the URA and evaluation processes conducted in the FIRST project, charities in Bulgaria had little knowledge of the kinds of barriers that people with ASD face when reading and the strategies which may be used to overcome these barriers [C3, C8]. Research led by RGCL bridged a gap in knowledge about ASD in Bulgaria and led to the derivation of a more detailed linguistic specification of these barriers (research findings F1 and F2). With this knowledge, for the first time, charities in Bulgaria serving children with ASD began to provide reading comprehension support for their service users. After the initial push provided by dissemination of project research findings, two other charities in Bulgaria continued work in this direction: the *ASSIST foundation* and the *Elia foundation*. Both are working to adapt reading support tools for people with disabilities in Bulgaria. The parents of children and adolescents with ASD who are supported by organisations like these are now being equipped with strategies to support their children's reading [C3, C8].

I3. Software Design and Development Company

Kodar Ltd (Bulgaria) gained knowledge in the FIRST project about text accessibility for people with ASD. As a result, they were able to design more accessible software (user interfaces). Kodar usually develops software applications for business users which use tables and forms, rather than text, to present information and enable users to enter data. Research finding F3 revealed important principles of interface design and Kodar exploited this knowledge to create user interfaces with minimal distracting elements, organising fields on the screen in a way that reflects the natural order in which neurodiverse users focus their attention. Kodar estimates that these interfaces have around 500 concurrent users, based mainly in the Netherlands and Belgium. RGCL research findings F1, F2, and F3 improved Kodar's design process [C4, C7].

The URA conducted in FIRST identified key concepts in user interface design that improve the comprehension of written text. Among these is the concept of personalisation, which emerged as an important feature of the OpenBook tool [C4, C7]. This finding proved valuable in three projects undertaken by Kodar, one of the consortium members, after the FIRST project ended. In these, Kodar developed portals for e-Learning and e-Testing and implemented analogous personalisation of those platforms for their users. This led to the development of portals which provide users with unique learning experiences. Each year, these portals are accessed by more than 2,000 students at Plovdiv University, the Bulgarian National Sports Academy, and the European High School in Economics and Management. This created changes in educational practices in higher education beyond the submitting unit.

5. Sources to corroborate the impact

C1. Testimonial letter from South London and Maudsley NHS Foundation Trust (Adult Attention Deficit Hyperactivity Disorder Service, Autism Assessment & Behavioural Genetics Clinic, The Bethlem Royal Hospital)
C2. Testimonial letter from Director of Autism-Europe
C3. Testimonial letter from President of the Parallel World Association
C4. Testimonial letter from Executive Director of Kodar EOOD
C5. Testimonial letter from Psychologist at Deletrea, Spain
C6. Deletrea webpage (https://www.deletrea.es/imagenesgoogle/CartaInstitucionDeletrea.pdf)
C7. Kodar EOOD webpage (http://www.kodar.net/en/#euProject)
C8. Parallel World webpage (https://bit.ly/3o4YkUT)
C9. Autism Europe webpage (https://www.autismeurope.org/easy-to-read/) (backup available at https://www.dropbox.com/s/r9ncjru3r0n3d3p/autismeurope_easyread.tar.gz?dl=0)