Sign Language Translation Mobile Application and Open Communications Framework

Deliverable 7.7: Final Impact Review

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Overview: This report provides an overview of the impact of the SignON project. It gives an outline of the impact that was described in the Grant Agreement and how this impact has been seen at the end of the project.

Revision History

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Approval Procedure

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V0.1	D7.7	Vincent Vandeghinste	INT	20/12/2023
V0.1	D7.7	Aoife Brady	DCU	20/12/2023
V1.0	D7.7	Joni Dambre	UGent	20/12/2023
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Acronyms

The following table provides definitions for acronyms and terms relevant to this document.

Acronym	Definition
API	Application Programming Interface
ASR	Automatic Speech Recognition
BSL	British Sign Language
CLARIN	Common Language Resources and Technology Infrastructure
DHH	Deaf and Hard of Hearing
DoA	Description of Action
GA	Grant Agreement
InterL	Interlingua
IP	Intellectual Property
ISL	Irish Sign Language
LSE	Spanish Sign Language
mBART	Multilingual Bidirectional and Auto-Regressive Transformer
MT	Machine Translation
NGT	Nederlandse Gebarentaal (Sign Language of the Nederlands)
NLU	Natural Language Understanding
SL	Sign Language/s
SLMT	Sign Language Machine Translation
SLR	Sign Language Recognition
SLTAT	Sign Language Translation and Avatar Technology Workshop
SOTA	State-Of-The-Art
SUS Rating	System Usability Scale Rating
UI	User Interface
VGT	Vlaamse Gebarentaal (Flemish Sign Language)
WP	Work Package

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1. Executive Summary

Hearing societies are built around the assumption that sound and speech are more primary than other forms of language use (writing; and languages expressed in a visual-gestural modality, sign languages). This phonocentrism (auditory bias), leads many deaf or hard of hearing (DHH) people to be excluded from accessing information in a society which is frequently communicated in an auditory modality (audio announcements, videos with no captions, etc.). While many assume that the provision of captions solves the modality gap, this is incorrect as the spoken and written languages of Europe are linguistically distinct from the signed languages of Europe. Thus, many signers experience the written languages of their home country as second languages, and literacy in these languages varies. Additionally, we note that hearing people face challenges in trying to communicate with people in DHH communities too, but while this may be an equivalent communicative challenge in the moment of communication, the challenge is not the same in terms of cumulative effort expected of deaf people to bridge communication gaps with hearing people. This burden is asymmetrical and impacts DHH people significantly more in their everyday lives, over the course of their lives. To try to address this challenge, the EU-funded SignON project aimed to develop a mobile application that will translate between different European signed and spoken languages. Over the three years of the project, it became certain that only by working together, e.g. through co-creation, acknowledging the strengths and weaknesses of all team members, relying adequately and without bias on the experience and expertise of deaf, hearing and hard of hearing professionals and by employing open and fair communication, language barriers can effectively be broken through.

The application, which has the form of lightweight software running on a modern mobile device with a camera, interacts with a cloud-based distributed framework dedicated to the computationally heavy tasks. The application and the framework were designed through a co-creation approach where DHH and hearing users worked together with SignON researchers and engineers to build a solution that suits all user types. Furthermore, it is built for easy adaptability to other languages (signed and spoken) and modalities other than text, i.e. audio and visual.

This project ran over three years from January 2021 to December 2023, and here, we present the impact of the project to date.

2. Introduction

One in a thousand people in the EU (approximately three quarters of a million million DHH persons) communicates in one of 31 national or regional sign languages (SL) as their first or preferred language. The SignON service aims to reduce the communication gap between deaf communities, people who are hard of hearing (including people with cochlear implants), hearing people (including family members and friends of deaf people), industry partners and policy maker user groups and promote inclusion of deaf communities into society by providing an open source and scalable solution for real-time translation between SL, text and speech in the languages that will be addressed in the project (Flemish Sign Language (VGT), Sign Language of the Netherlands (NGT), Irish Sign Language (ISL), British Sign Language (BSL) and Spanish Sign Language (LSE), as well as English, Irish, Dutch & Spanish spoken languages). SignON contributes to the repertoire of communication means and tools between deaf, hard of hearing and hearing people.

To accomplish this objective we developed a light-weight application that delivers the SignON services to its users. The SignON framework, which the application rests on, provides the "heavy lifting" to facilitate the processes of sign language recognition (SLR), the machine translation (MT), the sign language synthesis (SLS), the natural language processing (NLP) and other underlying tasks that, together, constitute the SignON mechanism for automatic translation between signed and spoken languages. SignON impacted the academic research, industry and business through its SOTA advancements in SL linguistics, SLR, Natural Language Understanding (NLU), Automatic Speech Recognition (ASR), Machine Translation (MT) and 3D avatar technology, and their underpinning fundamentals. Our platform and its constituent tools offer an alternative vision for the governance and values of SL translation and are publicly available to end-users in the form of a mobile app for real-time translation. Along with the technical and scientific innovations, SignON is a fundamental step towards an inclusive, fair research and innovation. Its vision is co-creation – a co-constructed, user-centric approach to draw use-cases and user requirements, to validate quality, to ensure acceptance based on continuous engagement with the stakeholders. As such SignON has become a stepping stone to foster communication, information exchange, business creation, learning and knowledge acquisition with an inclusive and open society, supporting the motto "Nothing about us without us!".

3. Expected Impacts as Defined in the Grant Agreement

The expected impacts outlined in the Grant Agreement (GA) address the expectations set by the programme call and were embedded in the original proposal (which later became the GA). Additional impacts were defined, including impacts specific to each consortium partner. These expected impacts are described below and the impact of each to the end of the project is outlined. Some of the wording of these is revised to make it more clear as they are taken outside of the context of the Grant Agreement. We add a footnote along with the revised impact for such revisions.

3.1 Expected impacts of the Project

SignON results have achieved impacts at multiple levels for user communities, business, industry and research stakeholders as well as the consortium partners. These are discussed in sections 3.1.1 (Expected Impacts as per the Call), 3.1.2 (Additional Impacts) and 3.1.3 (Impacts for the Consortium).

3.1.1 Expected Impacts as per the Call

The following impacts are the ones defined in the grant agreement as they appear in that document.

3.1.1.1 Improve multilingual speech processing on mobile devices:

SignON will improve multilingual speech processing by:

1. *Personalisable ASR for typical and atypical speech for English, Dutch, Spanish and Irish, accessible via the SignON application;*

2. *Enhancement and processing of the ASR output through language-specific NLU pipelines for improved message understanding and translation;*

3. *Exploiting a multilingual, multi-modal intermediate representation to capture the meaning of a message regardless of the source language and modality;.*

4. *ASR tuned to DHH speakers (atypical speech), and to our knowledge SignON is the first to provide this. Recent evaluations of ASR for the DHH community could only report about performances for standard ASR engines[1]. Thus SignON makes a significant step forward in inclusiveness. The same holds for the ASR and NLU facility for an under-resourced language like Irish. The ASR models*

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[1] Glasser, A. (2019) Automatic speech recognition services: Deaf and Hard-of-Hearing usability. CHI'19.

SignON will develop will be optimised for mobile devices and will be accessible online (communicating with a remote server hosting ASR models) or offline (models residing on the mobile device).

Impact Progress Indicators from the Grant Agreement:

1. *Improved speech to text recognition assessed by automatic metrics over all SignON supported spoken languages;*
2. *Increased preference in using speech to text by the users of SignON, for all SignON supported languages - automatically assessed via the SignON app;[2]*
3. *User satisfaction of translation based on speech input via voluntary user feedback based on a Likert 5-point scale;.*
4. *User satisfaction of mobile services of at least 68.0[3] System Usability Score (SUS).*

Progress Indicators:

SignON has improved multilingual **speech** processing in the following ways :

1. ASR for English, Dutch, Spanish and Irish is delivered via the SignON translation application; the SignON ML application allows data collection to personalise ASR models. Results on a (small) test set of atypical speech are positive.
2. Exploiting a multilingual, multi-modal intermediate representation to capture the meaning of a message regardless of the source language and modality (WP4);
3. ASR tuned to DHH speakers (atypical speech), and to our knowledge SignON is the first to provide this. Recent evaluations of ASR for the DHH community could only report on performances for standard ASR engines[4]. SignON's new transformer-based ASR models have demonstrated a significant improvement compared to the modular initial implementations in the SignON app. These new models certainly outperform earlier modular approaches for DHH speakers. However, lacking (training and evaluation) data, we could not substantiate this in our

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[2] This impact indicator is a revised version of the one mentioned in the grant agreement "Increased preference in using speech input to text reaching (at the end of the project) over all SignON supported languages - automatically assessed via the SignON app" in order to make it more clear as it is taken outside of the context of the grant agreement.

[3] 68.0 is a widely accepted standard; https://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html

[4] Glasser, A. (2019) Automatic speech recognition services: Deaf and Hard-of-Hearing usability. C HI'19.

evaluations. SignON made a significant step forward in inclusiveness with respect to ASR for Irish as an under-resourced language for which performances as targeted were achieved. The ASR models SignON has developed are optimised for mobile devices and accessible online (communicating with a remote server hosting ASR models).

4. The ASR component developed in the SignON project will steer the advancement of end-to-end ASR systems in the near future, both for under-resourced languages and for atypical speaker groups (speakers with hearing impairment or speech production impairments). During the project time we witnessed the overarching and massive impact of AI in the scientific field of ASR – it can be foreseen that this impact will only grow in the coming years. As such, the experience gained during the SignON project has and will have a substantial impact on our expertise with fine-tuning and testing larger AI-based ASR systems, in addition to the knowledge of setting-up future large scale GPU-based ASR web services.

Additional Progress Indicators

Following the reviewers' suggestions from the MidTerm Review, along with the continued progress along these indicators, additional focus has been directed to the development of the SignON SLR (Sign Language Recognition) and SLS (Sign Language Synthesis, i.e. Avatar) functionality with a tangible output. We worked to develop demonstrations of the latest versions of the SignON App and facilitating potential users' structured feedback and suggestions for its UI (as in D1.9) at co-creation events to achieve the following key progress indicators:

1. A new Milestone (MS11) demonstrating the SignON App with SLR and SLS services at TRL 5 (technology validated in relevant environment[5]) by March 2023;
2. An enhanced final Milestone (MS12) demonstrating the SignON App with operational SLR and SLR services at TRL6 (system prototype demonstration in operational environment) by the end of the project in December 2023.

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[5] h2020-wp1415-annex-g-trl_en.pdf (europa.eu)

3.1.1.2 Improve sign language recognition on mobile devices (as per GA):

SignON will deliver a mobile application with support for SLR based on single-camera video. While other technologies for SLR use excessive hardware (e.g. multiple cameras, wearables, etc.), SignON will fuse together state-of-the-art AI technologies - for face, hand and posture estimation - in an SLR component with improved performance. The SLR component will be based in the cloud, making the application available on any modern mobile device with a camera, without the need for specialised hardware or customised phones. Its distributed architecture will allow for parallel processing of computationally expensive tasks on high-end servers, leading to reduced latency alongside the high recognition accuracy. As SignON will support multiple SLs (see below), and because it will not require expensive special equipment it will be a highly inclusive solution for SLR on mobile devices.

Impact Progress Indicators from the Grant Agreement:

1. *Improved SLR according to automatic metrics, e.g. accuracy, comparable to academic SOTA results under similar conditions;*
2. *Increased preference in using SL recognition to text input or speech recognition (for signers who can speak) for all supported SLs - automatically assessed via the SignON app;*
3. *User satisfaction of translation based on SL input via voluntary user feedback based on a Likert 5-point scale.*
4. *User satisfaction of mobile services of at least 68.0 System Usability Score (SUS).*

Progress Indicators:

1. SignON has delivered a mobile application with support for SLR based on a single-camera video (WP2, D2.6, D2.7 and WP3, D3.2). While other technologies for SLR use excessive hardware (e.g. multiple cameras, wearables, etc.), SignON has fused together state-of-the-art AI technologies - for face, hand and posture estimation - in an SLR component with improved performance. The SLR component is cloud based, making the application available on any modern mobile device with a camera, without the need for specialised hardware or customised phones. Its distributed architecture allows for parallel processing of computationally expensive tasks on high-end servers, leading to reduced latency alongside the high recognition accuracy. As SignON supports

multiple SLs (see below), and because it does not require expensive special equipment it is a highly inclusive solution for SLR on mobile devices.

2. In addressing indicators 1 and 2, D1.6 reports that the final SignON SLMT service meets the project's target KPIs to a high degree, achieves a substantial degree of usability but falls short in terms of users' translation needs. Users' feedback indicates that the SignON SLMT V3.0 service is easy to use and navigate, and that it is clear how to secure a translation. Users also report that the speech to text and sign language for a choice of languages is very useful, as is speech-to-text and sign language support for multiple languages.

3. On indicators 3 and 4, users rated the difficulty of using the SignON SLMT App as 2.3 ("Low"). This "Low" difficulty score indicates that a usable TRL 6 prototype app has been developed and is a good foundation for the future evolution of the SignON service, for all users. The SignON open Framework and Apps provide an excellent foundation for future R&D, and a valuable resource for the DHH community.

3.1.1.3 Deploy solutions allowing wide take up by people who are deaf or hard of hearing (as per GA):

Many past and current technologies and services for DHH people have been unsuccessful due to failure to meet users' requirements and/or expectations or due to the artificial setting of design and development, as well as due to the lack of available data sets. Through its co-creation workflow, SignON will positively impact user communities by responding to their self-selected needs for real-life communication. The users will drive this project and as a result, we will see the weight and importance of their decisions imprinted in the SignON service. Furthermore, our user-centric practices will set an example of how applications and services for accessibility and inclusiveness should be developed. In such a way, SignON will establish a standard for the development of user-centric technology through co-creation methodologies.

Impact Progress Indicators from the Grant Agreement:

1. *Constant increase in the number of active users (of intermediate and final releases) and users who have expressed interest in the final release based on demonstrations of and/or own*

experience with the intermediate releases and decrease in potential users with negative attitudes towards the proposed technology (measured through co-creation events, figures expressed in both absolute and relative values);

2. *Constant increase in the number and demographic spread of social media followers from the DHH cohorts and an increase in social media activity.*

Progress Indicators:

1. Through its co-creation workflow (WP1), SignON has positively impacted user communities by responding to their self-selected needs for real-life communication. Users have driven this project and as a result, we have seen the weight and importance of their decisions imprinted in the SignON service.

2. Our user-centric practices have set an example of how applications and services for accessibility and inclusiveness should be developed, receiving significant positive attention - for example, in 2023 SignON was awarded the Science Foundation Ireland Award for Engaged Research as well as the ADAPT Centre Education and Public Engagement Excellence Award award. Thus, SignON has established a standard for the development of user-centric technology through co-creation methodologies.

3.1.1.4 Addressing under-resourced languages (as per GA):

SLs are under-resourced and are under-analysed relative to spoken languages. There is a need to develop resources in SLs and to describe the languages of interest more fully as we go. The SignON project will strengthen the position of the supported SLs by contributing to the documentation of sign languages and by developing advanced technology that will allow different forms of translation between languages and modalities. The SignON framework will include automated mechanisms and methodologies for expanding, improving and verifying the service. It will facilitate the inclusion of new languages via the SignON technology for learning from user content which is intended for low-resource scenarios or, thanks to SignON's modular design, via new and upgraded tools and models. Through SignON's learning capability, new resources can be collected and existing ones verified. The interactive 3D-puppeteering we will develop within this project will allow, through co-creation, to indefinitely expand the database of signs, validate and increase the quality of the automatic generation of Virtual Signers. In combination with the resources that can be collected through the SLR and ASR, SignON can create new parallel

corpora. Extending the corpora pool will reduce a significant gap for data-driven methods for recognition of sign and speech. As such it will impact the advancement in this trend of research. In this way the SignON project will not only impact the users of the SignON service, but also the research and development communities and enable them to advance the SOTA in ASR, SLR, avatar technologies, SL translation and synthesis.

Impact Progress Indicators from the Grant Agreement:

1. *Positive user assessment of the QoS for low-resource languages such as Irish;*
2. *Validation of the machine learning technology of SignON by the academic (citation number of SignON publications) and the user community;*
3. *Deploying new or extending existing corpora of speech-to-text, SL-to-text and SL-to-speech corpora as well as database of SL (monolingual data) for Virtual Signers research and development.*

Progress Indicators:

1. Together with the data collection activities, i.e. collecting and processing existing data (D3.1), we also created new datasets, such as the datasets described in Vandeghinste et al. (2022)[6] and De Sisto et al. (2023).[7] Partially funded by the ELE project, the NGT HoReCo, which began as a translation of hotel reviews into NGT, turned into a bigger initiative where data for VGT, LSE, Spanish, Irish (GA) and ISL have been or are still in the process of producing. Through activities like this,[8] SignON aids in extending the corpora pool.

2. The research on the linguistic aspects of the involved languages has contributed to the documentation, analysis and standardisation of SLs (D3.3) which, in turns, raises awareness and strengthens the support for inclusion of sign languages in the NLP discipline.

3. The SignON ML application (D2.8 and D2.9) facilitates the collection of user-generated content that can be used to update the underlying services. Together with the mechanisms for

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[6] **Vincent Vandeghinste, Bob Van Dyck, Mathieu De Coster, Maud Goddefroy and Joni Dambre** (2022). BeCoS corpus: Belgian Covid-19 Sign language corpus. A corpus for training Sign Language Recognition and Translation. *Computational Linguistics in the Netherlands Journal*. Vol. 12. pp. 7–17.

[7] **Mirella De Sisto, Dimitar Shterionov, Lien Soetemans, Vincent Vandeghinste, Caro Brosens (2023).** NGT-HoReCo and GoSt-ParC-Sign: Two new Sign Language - Spoken Language parallel corpora. In *Proceedings of the CLARIN Annual Conference* . Leuven

[8] The Gost-ParC-Sign project is another example of the impact SignON has made. It is a data collection and processing initiative funded by the European Association for Machine Translation (EAMT).

fine-tuning the InterL (D4.11 and D4.12) we provide a framework to include new languages and / or to update existing models.

4. Through SignON's Animics system, users can create new resources for signing avatars as well as validate and edit existing SL production datasets, with a major flexibility of re-use (D5.1, D5.2, D5.6, D1.12). Through the Performs system, flexible customisation, and multiple outputs (including easy embedding in web pages) are enabled.

3. The quality of service, according to our evaluations with users (D1.6) and the automatic quality evaluation of the recognition and translation (sub)systems (D4.5) has not reached acceptable levels. But our analysis indicates that (i) our systems are at a par with other state-of-the-art developments (ii) the stakeholders are well informed (as they have been throughout the whole project) and there is a steady progression in both the development and the (potential) adoption of such technology, (iii) there are guidelines and principles that have been established to facilitate the future developments and (iv) we have developed not only a framework that can easily be modified to accommodate other tools but has a (self-)learning capacity.

3.1.1.5 Open Source Framework and Application Programming Interfaces (APIs) (as per GA):

The SignON Framework, Application and cloud platform, which features its next-generation multilingual, multi-modal user-centred functionality, will be published free and open-source, to allow the inclusion of third-party functionality and modules for existing and future applications, services and languages. Through standardised APIs to the SignON services as well as to its underlying components - the ASR, SLR, InterL, NLU, and SL Synthesis - other tools and frameworks can exploit the results of this project and benefit from their functionality independent from the usage domain, objectives and technology. For many, this would translate to compliance with ISO/IEC 40500:2012.4 9.[9] This will enable the SignON Framework to become a de-facto tool in industry and academia.

Impact Progress Indicators from the Grant Agreement:

1. *Increasing community, traffic and contributions of the open-source code released on GitHub;*
2. *Use of APIs in other projects or products within the lifecycle of the project;*
3. *Number of citations/mentions of the SignON framework or APIs.*

Progress Indicators:

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1. During the project, the SignON Framework, Application and cloud platform has been designed, developed and finalised (WP2, D2.2-2.7 and related to the ML interface D2.8, D2.9).

2. Thanks to the modularity and the flexibility of the microservices-based approach of the SignON platform, all the updated components were easily integrated, enabling all the envisaged user's input/output modalities. For the same reason, it was possible to move the message synthesis component (i.e., the 3D Engine for avatar animation) into the SignON Mobile App, greatly reducing the 3D scene loading time and the used bandwidth for the end-user.

3. The final SignON platform has been deployed to an environment with GPUs support, assuring faster translations and enabling effective user communications. The code-base of the SignON Platform (hosted on GitHub) was updated and its licensing was defined in agreement with the consortium, to enable its public release and allow community access (D2.1).

3.1.2 Additional Impacts

3.1.2.1 Greater autonomy: [10]

Automatic translation from a sign language to a written text (e.g. from VGT to written English) enables Deaf signers to communicate independently in that written language and, for example, write emails without assistance. Deaf signers can engage with hearing speakers immediately, without the delay (sometimes days/weeks) and administrative burden often associated with securing authorisations for providing a face-to-face interpreter. This also allows for more immediate engagement with the wider hearing community in low-risk scenarios. Note that, SignON does not seek to replace face-to-face interpreting for scenarios that are more likely to entail higher degrees of risk, e.g. legal and medical encounters among others.[11] This is something that has been emphasised through our engagement with DHH communities and which we are especially mindful of. We emphasise that SignON does not seek to replace face-to-face human interpreting when such is available, but aims to extend the repertoire of communication means.

Impact Progress Indicators:

1. *Users indicate advancement towards greater autonomy in co-creation surveys from the beginning and end of the project.*

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[10] This impact, initially stated in *D7.6 Second Impact Review*, has been reworded for clarity.

[11] The list is in fact long and more nuanced than simply "high-" and "low-risk" encounters or use-cases. Here we use this simplification, as it also stems from user feedback, to better organise our work. We note that in the future continuous and more elaborate investigations will be needed.

Progress Indicators:

The use cases agreed upon reflect contexts that DHH people were keen to see developed. This reflects our commitment to respecting the input received from DHH communities. It also reflects the reality of what we can do given sign language data constraints and our as yet incomplete descriptions of the grammars of signed languages. In particular, the hospitality domain was preferred as a domain of application of SignON through the Flemish Deaf community (result of Flemish survey) which was then our starting point.

As reported in D1.6, users see the prototype SignON SL MT App's potential, and agree that it is a good foundation for the future evolution of the SignON service for all users, however it now needs to be upgraded to an operational product in terms of speed, accuracy, customization, and user interface. The users rated the final prototype SignON Mobile SL MT App V3.0 with an overall System Usability Score (SUS) of 57.9 overall. The D1.9 pre-SL app tasks was rated 8% higher at 62.6 (overall), 63.0 (signers) and 62.5 (non-signers), while the initial fast prototype app of D1.4 was rated 39% higher at 80.2 (overall), 77.1 (signers) and 83.8 (non-signers), which were above the acceptability threshold. While being more critical of its operation, the users' feedback provide a wealth of detailed input to the future user requirements of how SignON can provide a free and open-source multi-modal SL MT app and services framework between different signed, spoken and written languages that will go beyond current partial applications.

3.1.2.2 Potential to leverage SignON to supplement the work of face to face interpreters:

In cases of incidental conversation, e.g. when human interpreters require a break, but a deaf participant attending an event may wish to have a chat with another person/network or where the deaf person wishes to engage directly without working via a human interpreter, for informal conversation with a peer over a break in a meeting, for children in playground engagement (i.e.), etc..[12] SignON is going to facilitate such communication.

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[12] Revised from the grant agreement to make it more clear within the context of this deliverable.

Impact Progress Indicators from the Grant Agreement:

1. *Endorsement of the SignON application by SL interpreter services, e.g. Irish Remote Interpreting Service (IRIS)[13].*

Progress Indicators:

The SignON application is not yet at a stage of readiness to fulfil this function.

3.1.2.3 Multiplier effect of SignON technology as a resource:

Potential to leverage SignON by users, language learners (including parents of deaf children, teachers, friends), "hearing" environments (employers, colleagues, shopkeepers, pharmacy, etc.), interpreters, deaf people, as a point of reference. For example, hearing SL learners could use the SL recognition and translation to their spoken language to assess their progress. In the future, it might be possible for Deaf interpreters to use the SignON application as a tool to assist in interpreting from a spoken language to a sign language (currently they frequently use a hearing "feed" interpreter as an intermediary, or live captioning provision, which entails extra costs for the customers). As noted in the previous indicator, whether this will be the case or not, depends on the quality of the machine translation and the application, still in development and prototype releases, but also on the involved users (incl. interpreters). It boils down to whether or not deaf people decide to use the app in a specific context.

Impact Progress Indicators from the Grant Agreement:

(Indicated in co-creation surveys at the beginning and end of the project (users who are learners of SL))

1. *Adoption of the SignON service in education, i.e. as a possible learning tool for sign language students.*

Progress Indicators:

1. The quality of the translation is not at a level acceptable to users (D1.6 and D4.5). However, with respect to the available technology embedded in the SignON application and framework, it is a matter of improving the recognition, translation and synthesis models (through more,

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[13] https://slis.ie/iris/

higher-quality data, through user feedback, through use-case specific models, etc.) to get closer to this objective.[14].

2. Context needs to be taken into account as is the case with human interpreters but not yet with the SignON app. The SignON ML app provides a first step towards using user-generated to develop custom models; the Animics system (D5.6 and D1.12) provides a way to generate custom avatars, allowing future development to take into account context (to a certain extent).

3.1.2.4 Machine Translation:

The project will provide access to other SL corpora and the opportunity to produce valuable research into the linguistics of these under-resourced languages with a view to developing state-of-the-art machine translation tools that have the potential to facilitate better communication between DHH and hearing people.

Impact Progress Indicators from the Grant Agreement:

1. *New corpora published to open-access repositories (e.g. http://opus.nlpl.eu/);*

2. *Improved MT performance measured by standard evaluation metrics such as BLEU and TER as well as judged by human evaluators (deaf and hearing);*

3. *Validation of the machine learning technology of SignON by the academic (citation number of SignON publications) and the user community.*

Progress Indicators:

1. In addressing indicator 1, a parallel dataset (HoReCo) has been created with reviews of hotels. The dataset contains 297 parallel segments in 2 sign languages (NGT and VGT) and 4 spoken languages (English, Dutch, Spanish and Irish). Currently, the hotel reviews are being translated into a third sign language, namely, LSE. A second data collection project stemming from SignON, the Gold Standard Parallel Corpus of Sign and spoken languages (GoSt-ParC-Sign), is still ongoing and will be concluded by the end of January 2024; this dataset focuses on semi-spontaneous VGT material which is currently being translated into written Dutch. Similarly, the SignON project has participated in the organisation of the shared task WMT-SLT (https://www.wmt-slt.com/)

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[14] As it is with text-to-text machine translation, despite all the advancements, it is the case that human translation or interpreting cannot be replaced and we believe that despite the future progress of SLMT, human interpreters will not be replaced.

where public training datasets have also been generated.

2. In addressing indicators 2 and 3, although the translation quality obtained for SLMT is not satisfactory from the users' point of view, the comparison of the results in public datasets such as WMT-SLT reported in D4.5 show that they are at the state of the art level.[15] Accordingly, 17 articles about Machine Translation have been published with 73 citations in total and edited the proceedings of two workshops (AT4SSL2021 and AT4SSL2023).

3.1.2.5 Clear social justice and equality agenda that we help to achieve via SignON:

The SignON project will promote fairness and equality through the inclusive approach of developing the SignON service that brings the DHH and hearing communities in an open dialogue mediated via the experts in our consortium. Through better understanding of communities' individual needs as well as the requirements to facilitate fair communication between them, SignON will deliver a communication service that will reduce social inequality and inclusion imbalance.

Impact Progress Indicators from the Grant Agreement:

1. *Transparent reiterative cycles of discussion practising active engagement with and between DHH and hearing communities across the life of SignON.*

Progress Indicators:

The SignON project has sought to promote fairness and equality through the inclusive approach of developing the SignON service, bringing the DHH and hearing communities in an open dialogue mediated via the experts in our consortium. Through better understanding of communities' individual needs as well as the requirements to facilitate fair communication between them, SignON has worked to deliver a communication service that will reduce social inequality and inclusion imbalance.

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[15] We ought to note that the method we proposed within SignON is similar to the approaches reported in the 2023 edition of the WMT shared task on SLMT. However, in our evaluation we did not fine-tune our models on the WMT data and tested their generalisability. Although the metrics indicate a very low quality, the values are at a par with submitted systems, surpassing the baseline.

3.1.2.6 Education:

The learning from the SignON project will offer a new resource to facilitate the instruction of life skills among vulnerable deaf people with limited literacy skills which DCU, as a third-level educational institute, would look to initiate. It will also allow further development of certain SL grammar books and will lead to a significant speed up in the annotation of SL corpora. In this way, strong points of two independent groups can be joined to come up with something completely unprecedented, allowing easy access to syntactically annotated SL corpora which is something that KU Leuven wishes to exploit.

Impact Progress Indicators from the Grant Agreement:

1. *Schools, universities and organisations representing and supporting deaf people present the platform as a way to engage with deaf people in a more human way reducing barriers to communication and promoting inclusion;*
2. *Endorsement of the platform by Deaf communities, interpreters and hard-of-hearing people in the pilot sites.*

Progress Indicators:

1. We have responded to questions arising within the consortium regarding aspects of the grammars of the signed languages we have been working with which had not been addressed prior to SignON. D3.3 outlines this work.
2. As the SignON MT service does not deliver sufficient translation quality, it has not been endorsed. However, we ought to note the increase in positive reception, outlined in D1.6.

3.1.2.7 Lowering gender bias:

SignON will bring a service that lowers gender bias: (i) ASR, SLR and SL Synthesis will be adaptable to the user's preferences, including gender; (ii) the recognition, translation and synthesis tools will be developed following SOTA research on reducing gender bias, e.g. using gender-balanced data; (iii) participants in co-creation events will be selected in a gender-balanced way; (iv) with the 60/40 distribution of male to female institution leaders in our consortium the SignON project will be a positive example of unbiased synergy.

Impact Progress Indicators from the Grant Agreement:

1. *Ethics guidelines are observed;*

2. *The co-creation approach and the measurements for reducing gender bias we develop within the SignON project are adopted by other European initiatives and projects.*

Progress Indicators:

While this impact has been defined in the grant agreement, we need to clarify several aspects and revise others in order to address it adequately reflecting on biological sex as well as on the gender dimension beyond binary.

- When it comes to "*(i) ASR, SLR and SL Synthesis will be adaptable to the user's preferences, including gender*" we need to make two distinctions. From a language perspective, there is a lot of variety on how gender is marked depending on characteristics of the language itself. From those that explicitly mark gender, most only have crystallized approaches to handle binary gender (i.e. male/female). Although efforts are made in various languages to be more inclusive by the introduction of additional (neo)pronouns, data for these relatively new language phenomena is still emerging and, in many cases, needs to be consolidated by the respective language policies. As such, the currently available data and models do not yet accurately reflect certain societal changes that are taking place. Furthermore, in terms of ASR, while it was previously relatively common to use the gender of the speaker as a feature to steer the recognition process, it is not a sound criterion to use gender as a proxy for, e.g. voice pitch.

- From an avatar perspective, we need to note that the customisation options of our avatar goes beyond binary gender. At present we have EVA signing in our application with biological female characteristics. We believe that these insights will resonate in future projects and policies on language technology and inclusion.

- Across SignON we developed clear ethical guidelines and embedded these in all our work. The composition of the SignON consortium has undergone several changes throughout the span of the project. In terms of biological sex, at the time of writing this deliverable, it has a ratio of 35%:65% female to male members with 3 female and 5 male WP leads; the SAB, while initially composed of 3 female and 3 male members, at present consists of 2 female and 4 male. We also were highly conscious of the need to work towards better representation of DHH people in teams like SignON.

3.1.2.8 OpenSource tools for web-based interactive 3D graphics:

UPF-GTI will be able to extend the capabilities of the OpenSource tools for web-based interactive 3D graphics it has been offering to the community through GitHub, improving the capability to edit, animate and render virtual characters with much higher quality.

Impact Progress Indicators from the Grant Agreement:

1. *Increased traffic to the GitHub repository;*

2. *Endorsement of the 3D virtual signers and puppeteering system by other European projects, researchers and industry stakeholders.*

Progress Indicators:

A significant maturity of the SignON synthesis system has only been achieved at the final stages of the project and the consequent impact is expected after the project ends.

The progress in the second half of the project has already resulted in two emerging impacts outside the project (second indicator):

1) an international collaboration of UPF-GTI with the University of Amsterdam's SignLab through a project started in the final months of 2023, *Visual Signals for Language Technologies*[16], involving three other UPF research groups, in Vision, in LSC (Catalan Sign Language) and in Prosody.

2) plans for a comparative JASigning / SignON synthesis evaluation with end users, related to Bastien David's PhD Thesis (University of Geneva) in relation with the BabelDr project.

The full documentation, and tutorials of the system in GitHub is an activity currently under way. UPF-GTI and the media technology provider Brainstorm are currently exploring joint projects to support the needs of broadcasters.

UPF-GTI is a founding member of AccessCat, a network to promote innovation in accessibility, and plans to use it to push the impact of the project outcomes within the Catalan area.

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[16]
https://www.upf.edu/web/mdm-dtic/projects/-/asset_publisher/eCFIkRR4PbC1/content/visual-signals-in-language-technologies/maximized

3.1.3 Impact to consortium partners

The collaboration between the partners of the SignON consortium will expand their professional network and will create new avenues for knowledge transfer. It will have a common as well as an individual positive impact. Here is a rundown of the impact that our consortium partners have seen to date:

DCU: Our role in SignON will strengthen the position of DCU as a leader in MT and Engaged Research, particularly as we recently accepted the Science Foundation Ireland Engaged Research Award 2023. This project is contributing greatly to the many projects within DCU working towards educational equality for DHH students, including the ISL STEM Glossary project and the Bachelor of Education (ISL). This project will have practical use to the Deaf staff and students studying and working in the Faculty of Education in DCU. Our role in the co-creation work package has given us the opportunity to explore novel approaches to community engagement and engaged research practice, including two art-science projects: 'All the World's a Screen' was a Science Week event combining theatre, SLMT, and audience discussion; and 'That is the Question' is a short film combining Shakespeare and SLMT, which will tour to arts and cultural spaces to spark conversations about the future of SLMT.

FINC: The SignON project allows FINC to continue its effort and commitment in the development of accessibility services for current and prospective customers. Thanks to the leading role in WP2 and to the interaction with partners, FINC had the chance to be involved in the co-creation of the SignON App, and in the design and implementation of the SignON Open Framework and services, which helped FINC be engaged in different activities ranging from user requirements and needs of DHH people and deaf communities to backend design and implementation, to the interaction with research groups responsible for the implementation of specialised pipeline services. The realisation of the Machine Learning Interface for the extension of models and services developed throughout the project is another task in which FINC could apply its competences at the service of different partners in the project. Moreover, as a result of developing the SignON Framework with the SignON Orchestrator, APIs and services (T2.2 and T2.4), FINC had the chance to deepen its understanding of the specific technical requirements needed to support software modules in the processing pipeline and MT training, enhancing FINC capabilities as a system integrator to develop applications with a strong focus on accessibility services for all citizens.

INT: We have built a network of contacts in the sign language community and in the sign language research community. The SignON project has allowed INT to build up expertise in Sign Language data sets and multimedia datasets in general, and is now much more aware of the challenges in this area. It allowed us to increase our portfolio of language resources for the Dutch speaking area with resources on VGT and NGT. Apart from that we were also involved in hosting and setting up the infrastructure for the mobile apps, which was new for INT and has proven to be a great learning experience through the cooperation with FINC. INT als took initiative for new project proposals concerning SL research and resource building, and will keep on doing so, supporting the SL communities in the Netherlands and Flanders.

UPV/EHU: We have been involved in WP4, in the Machine Translation part of the SignON app. Our research group already had hands-on experience with text-to-text machine translation. However, we were new to the SLMT task and this project has been very valuable for learning about the deaf community, the needs of DDHH people and the current SLMT landscape. This experience has made the group open a new research line about SLMT and find funding to continue researching on this topic. As a result, in 2022, a SLMT project proposal in which we are part of the consortium was accepted and we will continue working on it even after SignON finishes.

MAC: As a result of developing and publishing the TRL6 prototype SignON SLMT mobile app V3.0 (D2.7) and the SignON ML training App V1.0 (D2.9), producing the iterative formative evaluation co-creation process in the "Technical Requirements & User Research (UX design) Reports" (D1.4, D1.9 & D1.10) and final summative evaluation (in D1.6), and documenting the required SignON app feedback at co-creation events, MAC staff are now much more engaged and better aware of the challenges, requirements and wishes of DHH people and deaf communities. The MAC team are also now more experienced in the use of structured formative users' evaluation and a user driven co-creation iterative technology design approach based on User Experience (UX) design thinking techniques. Working on WP2, MAC staff are now more aware of the technical options and potential of the open SignON app, framework and services. In task T2.4, the MAC team learned the requirements of MT training, from developing the SignON ML app to train the SignON MT. Researching the SignON market (D6.6) and developing the SignON Sustainable Exploitation, Innovation and IPR Plans (D6.6 & D6.7) the MAC Team have become very knowledgeable on the SLMT market situation, competitors, scope, challenges and exploitation potential of the open-source user-cocreated SignON apps, API and framework SLMT services. So MAC

staff are much clearer on a viable and realistic post-project roadmap to productise the current TRL6 prototype into a sustainable operational service (D6.7).

UPF: UPF-GTI is going to exploit the character animation advances of SignON within the recently started EMERALD EU project, where Brainstorm, an industrial stakeholder already mentioned, is partner as well. Further, we plan to integrate character animation in the XR creation tools of the MAX-R EU project, in its final year (at the moment of writing this report MAX-R is in its month 15 of its 30 month duration). As these tools are based on novel APIs (the emerging WebGPU and WebXR) and paradigms, this is expected to be significantly complex. Note as well the project recently started with other three UPF research groups and UvAmsterdam already mentioned. The TALN Group at UPF has started a new project on Natural Language Processing for Sign Languages (NLP4SL) with special interest in Spanish Sign Language (LSE) and Catalan Sign Language (CSL). This new venture aims at developing resources and tools for the computational analysis of SLs and it is being carried out in the context of a 4-years Spanish National Project granted to the Department of Information & Communication Technologies at UPF. The NLP4SL project has established a collaboration with the Department of Translation at UPF, the Universidad de la República, and the Universidad de Vigo. In addition, the group has secured an infrastructure grant from Oracle Research to boost our development of models for SL processing.

TUDublin:

TU Dublin were involved in WP3, in the linguistic investigation of the five sign languages of the project, and also in WP5, working on the SL lexicon and informing the development of a Markup Language that bridges the gap between the lexicon and the animation interface. It has been an invaluable experience for the TU Dublin team, learning about the technical challenges involved in developing a SLMT engine, while also furthering and deepening our understanding of the linguistic challenges involved in developing this type of software. We have secured funding for two further research students in the area of SLMT from the start of the project, whose work will further develop technology relating to SLMT, the productive lexicon and the automatic annotation of SL corpora, after the life of this project. The multidisciplinary nature of this project, has allowed us to build and develop collaborations with the SignON team and the broader SLMT research community, which have informed our own approach to SLMT and have also highlighted the importance of co-creation, ethics and integrity in the design and implementation of research projects within this domain. We have contributed and published many research papers and articles across the life of the project and presented SignON progress and challenges

for two years running at the START European Researchers night in Trinity College Dublin, Ireland. It has been an invaluable experience and we look forward to further collaboration and breaking new ground in the field in the future.

TCD: TCD led WP 9, which focused on ethics. We also contributed significantly to WP1 and to deliverables for WP3. Trinity College Dublin's Centre for Deaf Studies works on linguistic and applied linguistics issues, taking a multi-disciplinary approach to understanding the situation of deaf people in society and using action research methods to influence positive societal change. Our participation in SignON has further strengthened our experience in multi-disciplinary projects and the recognition of our approach to research via receipt of the Science Foundation Ireland Engaged Research Award 2023 for the SignON project has been very rewarding. Through SignON we have engaged heavily in co-creation activities and deepened our working relationship with Deaf and Hard of Hearing people and with Deaf community partners. We have benefitted from the collaboration with technical partners, which has allowed for further markup of corpora in Irish Sign Language, ensuring that data can be shared beyond the life of the project. We have learned a lot about the state of the art of SLMT and opened up potential future collaboration. Through our leadership on the ethics WP, have documented some of the ethical considerations of DHH communities and adopted key principles for SLMT work that we have shared via our open access deliverables and in a forthcoming volume on SLMT co-edited by Andy Way (DCU), Lorraine Leeson (TCD) and Dimitar Shterionov (TiU), with further publication in preparation (Loughrey et al.). We have also worked to document how depiction works as a driver of neologisms in ISL, which will, in turn, inform future work (e.g. Moiselle and Leeson 2022). SignON has opened up opportunities for engagement with colleagues working on Irish, which has prompted discussion of what a digital plan for Irish Sign Language would look like - something for us to work on beyond the life of SignON.

Additionally, members of TCD's Complex Software Lab (CSL) in the School of Computer Science and Statistics (previously University College Dublin) also worked on the SLR aspect of WP3 and WP4. The members of this team primarily worked in the development of SLR for ISL and BSL. We have greatly benefited from the collaborations we have formed with our partners over the course of the project, in particular with our colleagues working on SLR models in Ghent University. These collaborations have led to a number of contributions, including two in 2023, one led by TCD in transfer learning strategies for low resource SLR (Holmes et al., 2023a) and another in preparation led by Ghent University on robust sign embeddings (De Coster et al. 2023). On top of this work, we have published a contribution

investigating the most effective representations for signer independent representations (Holmes et al., 2022) and have another contribution under review to both identify the most salient pose keypoints for SLR models and identify potential shortcomings in pose estimation models (Holmes et al., 2023b).

The team in the CSL also benefited immensely from the interdisciplinary nature of this project. In particular we were tremendously grateful for the resources and insight provided by our colleagues in TCD's Centre for Deaf Studies. These included dataset curation activities, co-creation events and linguistic expertise. We hope to continue this interdisciplinary approach to SLR in our future work as it has enriched the quality of our approaches greatly. We have also collaborated with our colleagues in DCU and TCD in public engagement events over the course of the project. In particular we recently created a demo of SLR for the public at the SignON Project Showcase, ExploreAI, Douglas Hyde Gallery, TCD as part of START European Researchers' Night. Additionally we also had the opportunity to collaborate on the machine vision aspect of "That is the Question", a short film version of the Shakespeare-meets-AI performance, "All the World's a Screen" led by Shaun O'Boyle in DCU in collaboration with several other partners. Finally, another wonderful outcome of this project is that it has motivated the team to improve their own Irish Sign Language skills, with one PhD student even completing a module in ISL.

VRT: As a result of participating in the SignON project, and especially in the feedback that came from the co-creation workshops with the deaf and hard of hearing communities, the public media broadcaster VRT has received more in depth knowledge into which impactful changes it can implement to create more accessible media content. These learnings are being shared with producers and content creators in the organisation via internal presentations and workshops. It has also been discussed during face to face meetings with other public and commercial media organisations in Flanders (Belgium) and in Europe, through our own network Future Media Hubs (https://www.futuremediahubs.com/), the EBU network (https://www.ebu.ch/groups/access-services-experts), and the Flanders media network community Medianet Vlaanderen (https://www.medianetvlaanderen.be/en/). This helps spread the work and insights that have come out of the SignON project and may lead to ideas on how to implement solutions at media organisations.

What we also feel is that sign language is an unknown language to most hearing people. As such we are looking into ways to make sign language more inclusive and tangible; that it is being seen by more

people. One example of this is live signing during big public events organised by VRT, like "Zomerhit" and "De Warmste Week".

On the technological side, some part of the Deaf communities have asked for more subtitled content; this has led to VRT investing in two AI based subtitling projects, one together with 2 other Flemish commercial broadcasters DPG Media and Play Media. The Deaf community also mentioned the use (or non-use) of digital avatars. People prefer real people when used in professional broadcasts. However, this is a financially untenable situation due to the emergence of much more digital media content. VRT's innovation department is still researching the future possibilities to bring avatars into its new multifunctional studio which has a LED wall of 33 metres wide and 4 metres high, running on 5 Unreal Engines (https://www.vrtinternational.com/news/vrts-multifunctional-studio-a-view-to-the-future).

With the emergence of podcasts there is also a need to make those new audio formats available to Deaf people. Most of the solutions rely on subtitling. This could be one of the possibilities. Another one could be to apply digital avatars in a video representation of the podcast, as some Deaf people are not so fluent in written language (as it is not their main language). To make such podcasts cost optimised, an automatic pipeline should be created. The technical components from the SignON project could be a starting point for this.

VRT also learned a lot about data sharing. During the SignON project we learned that data is the "oil" for the AI components. But the sharing of data is bound to the rules of the GDPR and other legislation, like contracts with the sign interpreters to name one example. The SignON project led to a new approach at VRT for data management and sharing for AI purposes.

VRT has an advisory panel with multiple stakeholders where the Deaf community is part of. As we have experienced in the SignON project, it is very important to co-create with the Deaf community. Therefore VRT's innovation department has been included as members in these stakeholder meetings so that the communities will be included in new innovation developments.

VRT will also join the advisory panel of a project that has been submitted by VGTC, KU Leuven and INT when this project would be accepted.

UGent: The SignON project has allowed us to consolidate and extend our expertise on the extraction of useful information from sign language videos, in the context of a rapidly evolving technological (AI) landscape. It has strengthened the international collaboration with our European and Flemish partners and has helped us identify useful valorization tracks. From a scientific valorization perspective, UGent partners have published or contributed to 14 publications in journals or peer reviewed conferences, reporting about results from the SignON project, which together have more than 90 citations (according to Google Scholar, at the time of writing).

A prototypical demo of our embedding-based approach to dictionary lookup has been developed. It will be used to increase the awareness and knowledge about sign languages among the general public by participating to public events and the awareness about the possibilities of sign language technology among the Flemish deaf community through the stakeholders network of VGTC, and the awareness about commercial valorization possibilities among companies through networking, mainly using UGent's connection with imec. A first trial using this demo took place at the Flemish "Dag van de Wetenschap" (a multi-site event about science and technology) on November 26th (2023). Together, VGTC and UGent acquired funding[17] for the extension of this technology and its integration as a permanent component into the online Flemish sign language dictionary, which is freely available and maintained by VGTC.

A second funding application, mainly centred around the data needs for sign language recognition, sign language translation and sign language linguistic analysis, has been submitted with VGTC, KULeuven and ITN (decision still pending).

VGTC: Scientific communication, in other words communication and information dissemination about studies, research projects and scientific publications on sign languages, sign language users and deaf communities have always been a challenge within VGTC. The SignON project was a good opportunity to elaborate, test and evaluate this scientific communication to DHH individuals and communities. Among other things, we learned which approach worked best strategically so that the information reached the target groups efficiently, but we also learned that national sign languages were always more valuable than International Sign. We created a new roadmap (in the form of a white paper) to guide the research projects about sign language technology and their communication and dissemination. We learned that

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[17] Funding is secured through AMAI (amai.vlaanderen). This will be publicly announced at the end of 2023. However, due to the fact that the agreement has not yet been signed, no details can be disclosed at this stage.

expectation management and honest and transparent communication was the key to a mindset of the deaf communities about the domain "sign language technology". This is a useful lesson, especially as it helped us hope for more commitment from DHH and policy makers to produce and annotate more sign language data.

Radboud University: Radboud University greatly benefitted from the SignON project in the area of ASR (Automatic Speech Recognition). Starting from a classical modular based ASR architecture based on Kaldi, we moved to end-to-end approaches such as Meta's wav2vec 2.0 and the multilingual open-sourced OpenAI's Whisper[18] ASR models, and implemented these novel architectures for the targeted languages of spoken Dutch (including both northern and southern Dutch), English, Spanish and Irish. With this end-to-end approach, we achieved a significant improvement in recognition accuracy for nearly all speech recognition tasks in SignON. In the tests, the end-to-end ASR models achieve word error rates (WERs) of around 10%. Based on the test results, we eventually employed a medium-sized Whisper ASR model for English ASR and wav2vec 2.0 XLS-R model for Dutch-Flemish and Spanish ASR. It is important to note that a single model now covers both Dutch (Netherlands Dutch) and Flemish (Southern Dutch). Only in the case of Irish, a language that Wav2vec2.0 and Whisper are not pre-trained on, were we able to improve Kaldi to be better than the end-to-end solutions.

Apart from the improvement in terms of speech recognition accuracy, we also gained experience in terms of building architectures for ASR-based web services, the way the communication between client and server can be operationalized, and the various factors that impact recognition ('response') latencies of the ASR web service. Without doubt this will be very useful for future projects involving ASR, since it can be expected that near-future ASR systems will only run on high-end computing platforms.

The SignON project thus allowed us to explore best ASR approaches spanning a broad range from very-well-resourced to under-resourced languages. This expertise will benefit us greatly in future projects. This is also a relevant point of departure for developing ASR for atypical speech (which is notoriously under-resourced). Despite serious efforts, we were not able in this project to collect sufficient material for a meaningful training and evaluation for speakers from the DHH community, but the knowledge gained during SignON will be very fruitful in future ASR projects and with other types of atypical speakers, such as language learners and speakers affected by language and speech disorders.

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[18] https://openai.com/research/whisper

KU Leuven:

The Flemish Sign Language group at KU Leuven has a strong tradition in sign language research in the linguistic and sociolinguistic fields. The recent and ongoing rapid evolutions in AI and MT pose new and unprecedented challenges to this research community. As a result of the SignON project and the collaboration with (inter)national consortium partners, KU Leuven gained more insight into these challenges and how they might impact future research and projects.

KU Leuven therefore started exploratory research on the impact of video-mediated signing on the language use of Flemish deaf signers[19]. In addition, through the course of the project, KU Leuven gave linguistic support to technological developments by sharing its expertise and setting up research projects at the request of consortium partners[20]. This unique collaboration between academic researchers and technical partners yielded several good practices that will be taken into account in possible follow-up projects.

Furthermore, the Flemish Sign Language group at KU Leuven, in cooperation with the VGTC, strengthened its involvement with the Flemish Deaf community by means of a large-scale survey (in Dutch and VGT, see also D1.2 "Use cases & usage domains and stakeholders' acceptance") according to the co-creation principle. These research findings and methodology (found in a research report, available in Dutch and VGT)[21] can provide important guidance to give direction to new projects focusing on sign languages.

Additionally, the Computational Linguistics group at KU Leuven (CCL) covers a broad range of interests and skills within the realm of formal and computational linguistics, with applied experience in many NLP related topics. In SignON, the CCL has worked closely with other partners while working on a symbolic interlingua and glossing. Due to the nature of these topics, they have been actively involved in multiple

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[19]   Soetemans, L. & Vermeerbergen, M. (2023). When (shared) space and time don't matter. Remote video-mediated (synchronous and asynchronous) communication in Flemish Sign Language. IEEE International Conference on Acoustic, Speech, and Signal Processing Workshops (ICASSPW).

[20] E.g. Soetemans, L. & Janssens,M. (2023) Onderzoek naar constituentenvolgorde in Vlaamse Gebarentaal: enkelvoudige mededelende zinnen bij jongeren van 12 tot 18 jaar. Research report, KU Leuven, Campus Antwerpen & Vlaams GebarentaalCentrum.

[21] Soetemans, L. & Vermeerbergen, M. (2023). Use cases in het kader van het SignON-project. Research report, KU Leuven, campus Antwerpen.

work packages. Additionally, close collaboration with the Flemish Sign Language group at KU Leuven as well as the VGTC has been established which has lead to a better understanding of the challenges that everyone is facing. These collaborations have not only been fruitful within SignON but they have also sparked ideas for new projects outside of it. The network that was established will undoubtedly lead to further collaborations.

TiU: The SignON project has been a great opportunity for Tilburg University, and, in particular, the Department of Cognitive Science and Artificial Intelligence, to broaden its research line on inclusive MT by incorporating SL technology and processing. By doing so, it has also contributed to the creation of the Inclusive and Sustainable Machine Translation (ISMT) group which focuses on the research and development of inclusive and sustainable methods to the task of machine translation, including gender bias, sign language translation, environmental impact of MT and language technology and others. The impact of SignON on Tilburg University is going to be long-lasting: the research path initiated by it is already being continued by three funding opportunities – the ELE and EAMT fundings to work on data collection, which are in collaboration with partners from SignON, and a *starter* grant[22] funding a PhD project on SLMT (with a Deaf PhD candidate) and will likely be followed by the ISMT group. Finally, the SignON project has promoted the creation of collaborative networks with external partners working on SLs as well as with national sign language centres (such as the Nederlands Gebarencentrum).

EUD: The EUD works for equality in the public and private life of deaf people. SLs play a key role in achieving this equality and in the accessibility of deaf persons and human rights in general. To this end, the SignON project was an excellent opportunity to get truly involved in SLs, on both a human and technical side. EUD took the opportunity to include users in a co-creation process and to represent users as best as possible while collaborating with technical partners on the tremendous possibilities that the technology can offer. The inclusion of end-users was achieved by organising co-creation events in the scope of WP1. This way, valuable feedback could be gathered at the very start of the SignON project and throughout its life.

The inclusion of user feedback from the co-creation events and its analysis was necessary to address the needs of deaf people in line with the Convention on the Rights of Persons with Disabilities. The inclusion

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[22] According to the Administrative Agreement between the OC&W, the Association of Universities of Applied Sciences, and the Association of Dutch Universities (signed 14/07/2022).

of EUD in an EU project of this scale, makes sure that the needs and priorities of the deaf and hard-of-hearing communities are put to the forefront from the beginning. The importance of this must be underlined, as in the past very few projects included deaf users in the development from start to finish. This did not fit in with the "Nothing about us without us'' principle. EUD sincerely believes that the SignON project sets an example on the involvement of deaf communities. The involvement in a project of this kind also deepens and develops the internal knowledge at EUD regarding issues related to sign language technologies, co-creation, evaluation protocols, project management, use-cases, user requirements, science communication etc. which can be used for lobbying and/or future projects.

3.2 Measures to Maximise Impact

At the beginning of the SignON project a communication and dissemination plan (D6.1) was prepared. This plan ensures proper visibility, accessibility and promotion of SignON and its results during the project lifecycle and after its completion. We targeted 5 groups of users: (i) deaf communities (signers), (ii) DHH people (non-signers), (iii) hearing people, (iv) SL interpreters, and (v) scientific community. To reach all these groups in a timely and appropriate manner, the consortium relies on the extensive network already established by SignON participants representing the community and industry partners as well as the significant international reach of the External Advisory Board. We have already engaged and informed these groups through (i) scientific and popular publications; (ii) conference, workshop and seminar presentations; (iii) wide-ranging media coverage (newsletters, social media posts, press releases). In 2022 we presented different aspects of the project, including the avatar, the translation capabilities, etc., in our co-creation events, as well as at a workshop at the EU Parliament. The application and framework have been tested and validated by internal users. While the initial idea was to demonstrate the SignON framework and app in front of open audiences, we have decided to limit the outreach to selected members initially because we want to increase awareness before releasing a product that is undergoing continuous research and development. Having learned from previous experiences, presenting a product in development could be misunderstood or misinterpreted and lead to failure in future adoption.

In May 2023 SignON was invited to present at a workshop during the EUD general assembly, on the topic of sign language machine translation. SignON and EASIER[23] partners presented on different aspects of SL

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[23] www.project-easier.eu

technologies involved in the translation pipeline, and SignON partner Dimitar Shterionov presented on the topic of machine translation. At this event we (SignON and EASIER) engaged in an open discussion about the development and future of sign language technologies with the audience, composed of delegates representing the deaf communities of EU member states and Norway, Switzerland, Iceland and the UK. Following this event, the EASIER and SignON leads together with EUD decided to organise a final, concertation event where the outputs and outcomes of the two projects are shared with key stakeholders. This event took place on the 29th of November 2023 and was hosted by the European Commision (Brussels) and was attended, among others, by members of the commission, representatives from the technology sector and members of the COST LEAD-ME action.

In September 2023, we organised a morning session at World Deaf Day in Bruges, in collaboration with NAD in Flanders, and two subsequent workshops in the afternoon. We also delivered a final co-creation event in Dublin at Trinity College Dublin in December 2023. These showed that face-to-face meeting with DHH individuals were very productive. Concerns and ideas were exchanged and so we were able to increase their engagement by clarifying their role in the Sign Language Technology process, for example through their contribution to expanding data.

The SignON website, www.signon-project.eu, is the dissemination hub for our project. For the wider outreach, the content on our website is available in English and in International Sign (IS); the updated overview about SignON 2022 is translated to all national sign languages. Furthermore, the website and its content is developed by deaf professionals who understand the communication needs of deaf communities.

After three years, the SignON website, www.signon-project.eu, provides all essential information and offers an overview of public deliverables, scientific publications and videos. The FAQs page contains answers to questions regarding the conclusions of the three-year SignON project and outlines the subsequent steps.

But it also exposes bottlenecks in our communication and dissemination strategy. DHH individuals and communities preferred information in national sign languages rather than International Sign. However, constant information dissemination in five national sign languages around which we work at SignON (VGT, NGT, ISL, LSE and BSL) proved to be more time-consuming and expensive than in International Sign.

Even though we have a pool of deaf translators in these national sign languages, whom we can recruit to translate content on a freelance basis, the posts in which national sign languages are used naturally (rather than translating from a written text) proved to have better reach. This was not always possible as the communication staff knew only one national sign language, namely VGT.

The consortium has tracked market trends to identify business strategies and roadmaps for the exploitation of Intellectual Property (IP) arising from the project's work. Deliverable *D1.1 Case studies and evidence analysis* presents our first analysis of use-cases, market and prior research; we continued to do so on a regular basis. In doing so, we were able to identify new market trends and opportunities to incorporate new approaches while supporting efforts to demonstrate SignON's appeal and potential profitability to potential investors.

4. Impact Progress

Following Tilley, Ball and Cassidy (2018), we present an overview of how SignON impacts across four domains: **conceptual** impact, **instrumental** impact, **capacity-building** impacts and **enduring connectivity:**

Types of Impact	SignON Impacts
Conceptual: *impacts on knowledge, understanding and attitudes*	Until SignON, many deaf community members were at best ambiguous to, and at worst, strongly opposed to SLMT. SignON's co-creation approach and iterative engagement has opened up dialogue with DHH communities and helped present the state of the art to DHH people in their languages. This outcome has led to the impact of developing a more informed and engaged society. This does not automatically lead to more support for SLMT (it could generate more informed criticism) but it creates a closer connection between researchers and community members. SignON opened up dialogue across a highly diverse multidisciplinary team, introducing DHH communities' key concerns and ethical considerations for SLMT work which have shaped our project and, as a result of our publications, which will inform future SLMT work. Working across disciplines allowed for exchange of knowledge

	between AI, Computer Science, Linguistics, Deaf Studies and Interpreting Studies scholars and across academic, industry and NGO partners. This facilitated a greater understanding of what linguistic knowledge is currently documented with regard to the European SLs we were working on and the many gaps that exist. These, in turn, impact our SignON work. The interdisciplinary team also grew to better understand the key elements that colleagues working on technical WPs needed to have in hand and the major challenges they faced. This facilitated better understanding and fostered an attitude of sharing the gaps in our knowledge and considering the SignON work from end-to-end, factoring in these gaps. In addition, it has an institutional impact: universities, departments, business, teams, and others can adopt these learnings in their operations.
Instrumental: *impacts on changes in policy and practice*	Most research projects are not expected to have an immediate, direct impact on policy as they usually show a 'web of influence'. Our key influencer is EUD which facilitates not only the dialogue with the deaf and hard of hearing stakeholders but also with the European legislative bodies and policy makers. EUD's involvement in SignON has been instrumental in deepening our experience and understanding of SLT research and development. EUD has gained valuable experience in leading co-creation across various deaf communities, this along with involvement in other aspects of the project have allowed us to evaluate and map best practices with respect to science communication, community involvement and user evaluation. Through SignON, EUD has built a considerable network of academic researchers and industry partners active in this space, and are actively exploring ways to share the insights and knowledge from SignON with our body of member associations across Europe.
	Over the three years of SignON we delivered 53 academic publications in various conferences, workshops and journals. We have published 2 white papers and one more is being prepared. Along with this we have co-organised several international academic events dedicated to sign languages and sign language machine translation. These include the organisation of the well-established SLTAT workshop as well as new initiatives such as the AT4SSL bi-annual workshop (two editions were organised within SignON), the WMT shared task on SLMT (2022 was the first edition, followed with the second one in 2023), the special track on SLMT within the CLIN conference, the special track on SL processing at the ESANN 2023 conference. These not only bring different professionals together presenting an opportunity for exchange of knowledge and collaboration, but raise awareness of SL NLP within communities whose input and work have the

potential to push the state of the art forward, e.g. the machine translation research community, the deep learning research community and so on.[24]

We also compiled the book "Sign Language Machine Translation" which has captured a lot of the knowledge and experiences by the members of this consortium as well as from EASIER.[25] It is worth mentioning that a book captures perspectives, contextualisation, and opinions that are broader than (proceedings) papers. This leads to Impact on epistemology of SLMT.

The SignON and EASIER projects worked on a white paper which aims at bringing to the attention of policy makers the scarcity of language technology resources available for European sign languages. This paper stresses the necessity for more investments targeting those languages and the development of their resources. It has been published as an additional deliverable of the European Language Equality 2 Project. (Vandeghinste, Vincent, Mirella De Sisto, Maria Kopf, Marc Schulder, Caro Brosens, Lien Soetemans, Rehana Omardeen, Frankie Picron, Davy Van Landuyt, Irene Murtagh, Eleftherios Avramidis, Mathieu De Coster (2023). Report on Europe's Sign Languages. Deliverable European Language Equality II project).[26]

The SignON Consortium was invited by Ádám Kósa, a deaf Member of the European Parliament, to present the SignON project at the European Parliament in Brussels. We took the opportunity to also invite representatives of the National Associations of the Deaf from the project countries, to attend the presentation of the project in the European Parliament and afterwards hold a separate workshop to strengthen the bonds with the national deaf communities even further.

SignON and EASIER leads were invited to present at the EUD General assembly in May 2023. This presentation focused on the current advancements and future prospects of SLMT research, and engaged deaf community leaders from across the EU and

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[24] For a detailed list of the presentations, papers, demonstrations, organised events, etc. we refer the interested reader to deliverable *D6.4 Final Annual Report on Communication and Dissemination Activities*.

[25] The book, "Sign Language Machine Translation", Editors: Andy Way, Lorraine Leeson, Dimitar Shterionov, ISBNs: 978-3-031-47361-6/978-3-031-47364-7/978-3-031-47362-3 is under press and is expected to be published by Springer in April 2024. Initially the editorial board was composed by Andy Way, Lorraine Leeson, Dimitar Shterionov and Christian Rathmann, however, due to unprecedented workload, it was prepared by the first three.

[26] The paper is available at https://european-language-equality.eu/wp-content/uploads/2023/06/ELE___Deliverable_D1_40__Europe_s_Sign_Languages_.pdf and at https://zenodo.org/record/8047005

	associated member countries in productive exchange about how to shape the research going forward. The SignON and EASIER projects co-organised an all-day event at the European Commission in Brussels on 29 November 2023, titled "Outcomes and Outlooks of Research on Sign Language Technology in Europe". This event hosted representatives of SignON, EASIER and LEAD-ME projects as well as members of members of the European Commission, industry representatives and policy officers. This workshop was a venue that facilitated conversation and knowledge exchange that can lead to innovations, new projects and new collaborations. Hearing for the Interparliamentary Commision at the Flemish Parliament about language technology and cooperation with blind and deaf on 13/05/2022. Video available at: https://www.vlaamsparlement.be/nl/actueel/nieuws-uit-het-vlaams-parlement/taaltechnologie-en-samenwerking-voor-blinden-en-doven (in Dutch) Industry innovations/impacts? The project has successfully produced the SignON SLMT mobile App and Framework services as a pre-commercial prototype that has been validated and demonstrated. These provide a solid foundation for future development and productization of an open freely available accessible user-centered operational multi-lingual transmodal SLMT platform and its constituent tools, as an alternative vision for the governance and values of SL real-time translation. Thus, providing a new standard approach for SLT to all EU languages and foster communication, exchange of information, business creation, learning and knowledge acquisition with an inclusive and open society, and offer a real-time service co-created by the user. Policy / Community impacts?
Capacity-building: *impacts on the ability of researchers to conduct similar work in future*	From the 9 academic partners, 17 PhD researchers and postdocs/research assistants worked within SignON. They have developed competency in (one or more of) qualitative research approaches, ethical and data management training, SLMT (SPECIFICS), co-construction methodologies, in researching aspects of the linguistics of signed languages, gaining understanding of how their work informed/offered nuance to the technical teams and benefit from working within a multidisciplinary community of practice. As a result of SignON, partners with sign language corpora but without technical expertise have been able to learn more about curation of data sets and appropriate homes for same. Through

	deliverables, seminars, reports, etc. each learning is shared.
	SignON partners with no prior knowledge of DHH communities have learned about sign languages, Deaf culture, and engaged in meaningful ways with DHH colleagues and individuals from DHH communities. This has enriched understanding of the purpose, opportunities, and current limitations of the work we do on SLMT.
	The SignON consortium learned a lot about GDPR related obligations when handling qualitative data and research ethics protocols when collecting data from human subjects, as well as the challenges of collecting data from across many countries/universities/organisations when not all have ethics boards and when no easy pan-consortium one-stop solution exists.
	The SignON consortium published widely, with many Open Access outputs. Further material is forthcoming. All will continue to impact on the field of SLMT beyond the life of the project. See full list of publications below.
Enduring connectivity: *Impacts on the existence and strength of networks of people and organisations who understand and can make use of the research*	Several partners have already secured funding for follow-on projects while others are working on collaborative proposals / intentionally seeking funding opportunities. Without SignON, most of these relationships would not have occurred.

SignON also impacts academic research, industry innovation and business progression through its SOTA advancements in SL linguistics, SLR, NLU, ASR, MT and 3D avatar technology, and their fundamentals. When openly released, our platform and its constituent tools will offer an alternative vision for the governance and values of SL translation and will be publicly available to end-users in the form of a mobile app for real-time translation. In the first year of the project, SignON was mainly on an exploratory mission - to identify the needs and gaps, potential technologies and existing research in order to establish a new vision for translation between different EU sign and spoken languages through a service co-created by the users. In the second year of this project, we developed most of the necessary components through robust research activities, built models for recognition, NLU, translation, synthesis and integrated those components and models in an effective framework accessible via a lightweight

application. We continue to analyse and document the (hitherto under-documented) languages we are working with. During the third year, the SLR and SLS components were released and integrated in the framework.

As noted in Section 3.2., the target audiences were engaged and informed via (i) co-creation events, (ii) scientific and popular publications, (iii) organisation of and participation in conference, workshop and seminars, (iv) wide-ranging media coverage and (v) prototype presentations and demonstrations.

- ❖ Co-creation events: WP1 organised several interviews, either with multiple participants (a focus group), or with just one person. Interviews were held with participants from Flanders, Belgium, the Netherlands, Ireland and Spain, and also with European deaf individuals with specific backgrounds such as people of colour and deafblind. Furthermore, in-person co-creation events were organised; workshops took place in Dublin (Ireland) and Bruges (Belgium). Roundtables took place in Amersfoort (the Netherlands), Madrid (Spain), Stockholm (Sweden) and Dublin (Ireland). To ensure a diverse group of participants, people from different ages and genders were invited. The impact is such that the potential (DHH) users felt listened to during these co-creation events, which resulted in a strong willingness to follow-up further stages of SignON development (e.g. to test each component of the SignON services if they have the opportunity). The impact is the positive view on the SignON project, thanks to being aware that deaf people are involved from the start this time and that we actually listen to them.

- ❖ The SignON Consortium was invited by Ádám Kósa, a deaf Member of the European Parliament, to present the SignON project at the European Parliament in Brussels. We took the opportunity to also invite representatives of the National Associations of the Deaf from the project countries, to attend the presentation of the project in the European Parliament and afterwards hold a separate workshop to strengthen the bonds with the national deaf communities even further.

- ❖ The SignON and EASIER projects co-organised an all-day event at the European Commission in Brussels on 29 November 2023, titled "Outcomes and Outlooks of Research on Sign Language Technology in Europe".

- ❖ Scientific and popular publications: The list of work that spans from the SignON project and published in academic and non-academic venues is:
  - ➢ 2023
    - ■ Brady, Aoife, Clarke, Emma, Dunne, Jane, Kearns, Anne, Leeson, Lorraine, Mathews, Elizabeth, Moiselle, Rachel, O'Boyle, Shaun, Omardeen, Rehana,

Picron, Frankie, Shterionov, Dimitar, Van Landuyt, Davy; Realising Inclusive Design Through Co-creation; EARMA Conference, April 2023, Prague.

■ Declerck, Thierry, Sam Bigeard, Fahad Khan, Irene Murtagh, Sussi Olsen, Mike Rosner, Ineke Schuurman, Andon Tchechmedjiev and Andy Way (2023). A Linked Data Approach for linking and aligning Sign Language and Spoken Language Data. Proceedings of the Second International Workshop on Automatic Translation for Signed and Spoken Languages.

■ Shterionov, Dimitar, Mirella De Sisto, Mathias Müller, Davy Van Landuyt, Rehana Omardeen, Shaun O'Boyle, Annelies Braffort, Floris Roelofsen, Frédéric Blain, Bram Vanroy and Eleftherios Avramidis (2023). Proceedings of the Second International Workshop on Automatic Translation for Signed and Spoken Languages (AT4SSL), Tampere, Finland.

■ De Coster, Mathieu, Dimitar Shterionov, Mieke Van Herreweghe, Joni Dambre (2023). Machine Translation from Signed to Spoken Languages: State of the Art and Challenges. Universal Access in the Information Society.

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■ De Coster, Mathieu and Joni Dambre (in press). Sign languages as source language for machine translation: historical overview and challenges. In Andy Way, Lorraine Leeson and Dimitar Shterionov (eds), *Sign Language Machine Translation*. Springer.

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[27] This work is currently being translated in VGT and will be published on the SignON website upon completion.
[28] We are currently preparing a VGT summary of the report.
[29] The paper is available at ELE___Deliverable_D1_40__Europe_s_Sign_Languages_.pdf (european-language-equality.eu)

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❖ Organisation of and participation in conferences, workshops, symposia and other forums. In 2023, SignON co-organised two workshops - the Second International Workshop on Automatic Translation for Signed and Spoken Languages[30] (AT4SSL 2023), which was a satellite workshop of the EAMT Conference, and the already-mentioned workshop 'Outcomes and Outlooks of Research on Sign Language Technology in Europe'. SignON also co-organised the special session on "Machine Learning Applied to Sign Language" at the ESANN 2023 conference. In addition, SignON was involved in the organisation of the WMT Shared task on SLT, the 2022 Sign Language and Avatar Technology workshop (SLTAT 2022) and the CLIN 2022 special track on Sign Language NLP.

❖ Wide-ranging media coverage: SignON content is disseminated via its channels in Facebook (SignONEU), LinkedIn (SignON (EU project)) and Twitter (@SignONEU). A great success is the SignON encyclopaedia which presents videos containing information about sign language, avatars, deafness, machine translation and other interesting content related to the project topics. The SignON website as a dissemination hub.

Since the major update of the website and its publication, and the launch of the social media channels of SignON, our target groups are aware of our project. At the start of the project the general view was that the potential user groups still experience SignON as something not necessarily relevant to them personally. However, through the different communication and dissemination activities and co-creation events, these views are changing. It is obvious that through mutual understanding the project is evolving into a technological hub for all potential users. Not only "they know that the SignON project exists and what its purpose is" they now have an idea of the added value and the drawbacks of such a project and can make an informed decision when and whether to use the technology; they are more open to contributing and expressing their opinion about use-cases and the future of sign language translation and the use of 3D virtual signers (i.e. avatars). We have now created and populated an FAQ-page on the SignON website with questions and answers that originated from the various communication and co-creation activities. Furthermore, SignON has built collaboration bridges with other projects, researchers and organisations, including Dr. Maartje De Meulder, who presented along with the SignON

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[30] https://sites.google.com/tilburguniversity.edu/at4ssl2023/

consortium at the EU Parliament, a partnership with NGTC on organising co-creation events in the Netherlands, strengthening the relations with the EASIER project and others.

The dissemination activities that have taken place to date as part of the SignON project are further elaborated on in deliverable D6.3: Second Annual Reports on Communication and Dissemination Activities which will be submitted to the EU Portal at the end of December 2022.

The plans for exploitation routes within and outside the SignON consortium have been outlined and discussed in deliverable D6.8: "Final SignON Sustainable Exploitation, Innovation and IPR Plans", which will be submitted at the end of the project.

5. Conclusions

The outputs of the SignON project indicate its potential impact. In numbers: 76 deliverables (50 of which are public), 54 articles, a book, 8 workshops, conferences, symposia, and other outreach events such as demonstrations, invited talks and others, as well as 12 co-creation events and surveys spread over the regions of every involved language and an increasing numbers of subscribers, followers and views to our social media channels and website. SignON has impacted the deaf, hard of hearing and hearing stakeholders by raising awareness, introducing and establishing standards in translation technology and creating an exemplary inclusive approach - through co-creation. And despite the low translation quality, SignON has paved the way for the advancement of SL NLP in the right direction - through inclusive collaboration, fair and open communication and rigorous research and development.

This project has also impacted each consortium member by providing opportunities to learn from a multidisciplinary team and establish / strengthen a solid network. In addition, many of the members of this consortium have taken actions to keep the momentum of SignON going through new collaborative or individual projects, grants and funding.

We believe that SignON has also made a positive impact on policy makers and that in the future the lessons learnt in this project will resonate in national, European and global strategies for inclusion, education, language resources and technological innovation.

SignON represents a paradigm shift in SLMT research by bringing such a wide spectrum of expertise together in a single project. The new knowledge and technology generated as part of the project as well as the standard it sets for future projects are solid indicators of positive, long-lasting impact.