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Technology for subtitling: a 360-degree turn*

Tecnología para la subtitulación: un giro de 360 grados

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Abstract: Subtitling has become one of the most important audiovisual translation modes and cannot be understood outside the context of the technology that makes it possible. New audiovisual media are appearing, such as 360º videos, and the necessity of subtitling this type of content to make it accessible is emerging. In this article, an updated review of current subtitling technology is presented to contextualise the study. Then, a review of main immersive environments (3D, augmented reality and virtual reality) and their implications for subtitling has also been introduced. The focus of the study is on virtual reality and, therefore, the main challenges of subtitling 360º content are presented. To respond to the needs of subtitling this type of content, a prototype version of a subtitle editor has been developed and presented to twenty-seven professional subtitlers who have tested the tool and reported the correspondent feedback on usability and preferences. This study has proven the importance of carrying out usability tests with end users when developing specific software. Finally, the challenges faced by subtitlers in new audiovisual media such as 360º content are presented.
Keywords: Subtitling, subtitling technology, 360º content, reception study, usability.
Resumen: La subtitulación se ha convertido en uno de los modos de la traducción audiovisual más importantes y no puede estudiarse fuera del contexto tecnológico que la hace posible. Asimismo, nuevos medios audiovisuales, como los vídeos de 360º, están emergiendo y la

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necesidad de subtitular este tipo de contenidos para hacerlos accesibles es evidente. En este artículo se presenta una revisión de la tecnología de subtitulación existente para contextualizar el estudio. A continuación, se presenta una revisión de los principales entornos inmersivos (3D, realidad aumentada y realidad virtual) y sus implicaciones para la subtitulación. El estudio se centra en la realidad virtual y, por lo tanto, se presentan los principales retos de la subtitulación de contenidos en 360º. Para responder a las necesidades de subtitulación de este tipo de vídeos, se ha desarrollado una versión prototípica de un editor de subtítulos que se ha presentado a veintisiete subtituladores profesionales que han probado la herramienta y aportado sus opiniones y sugerencias. En este estudio se ha demostrado la importancia de realizar pruebas de usabilidad con los usuarios finales a la hora de desarrollar software específico. Finalmente, se presentan los retos a los que se enfrentan los subtituladores en nuevos medios audiovisuales como los contenidos 360º.
Palabras clave: Subtitulación, tecnología de la subtitulación, contenido en 360º, estudio de recepción, usabilidad.
Summary: 1. Introduction; 2. Subtitling technology: overview; 3. Immersive media and subtitling; 4. ImAc web editor; 5. Evaluation, 5.1. Evaluation setup, 5.2. Evaluation methodology, 5.3. Participants, 5.4. Evaluation results; 6. Conclusions; Acknowledgements; References.
Sumario: 1. Introducción; 2. Tecnología de la subtitulación; 3. Medios inmersivos y subtitulación; 4. Editor web de ImAc; 5. Evaluación, 5.1. Configuración, 5.2. Metodología, 5.3. Participantes, 5.4. Resultados; 6. Conclusiones; Agradecimientos; Referencias bibliográficas.

1. INTRODUCTION

We are experiencing a subtitling revolution. The distinction between subtitling and dubbing countries is becoming more and more outdated. Nowadays, on certain platforms the choice between subtitled or dubbed versions is made individually by each viewer and not imposed by distribution companies. The key aspect of this revolution is the new distribution model for audiovisual content based on Video on Demand (VoD) platforms such as Netflix, Prime Video, HBO, Hulu and the ones to come, such as Disney+ or Apple TV+. In these platforms, the viewers can access content from all over the world, in different languages and with different audiovisual translation modes available, mainly subtitling and dubbing. Subtitling has become such an important element in audiovisual communication that it has recently been the focus of a heated debate. Netflix decided to include Castilian Spanish subtitles for the film *Roma* (2018), which was filmed in Mexican Spanish, by the Mexican award-winning film director Alfonso Cuarón. Some viewers and linguists disagreed with this approach, and Cuarón himself considered the subtitles "provincial, ignorant and offensive to Spaniards themselves" (Cuarón quoted in Morales *et al.*, 2019: online). Due to social pressure and the

comments from the director, Netflix ended up removing the Castilian Spanish subtitles for this film.

Changes are also being introduced in the way audiovisual stories are created. Recently, the first interactive series episode was launched by Netflix, accessible via computers, smartphones or Smart TV. The episode called "Bandersnatch" is part of the science fiction series *Black Mirror*. The main character of the episode set in the 80s is an aspiring video game programmer who is working on coding a game based on a choose-your-own-adventure novel called *Bandersnatc*h. In this episode, the viewer has the control over the main character's decisions through the story, leading to a myriad of different endings (Harris *et al.*, 2019). Also, new technology such as virtual reality (VR) or augmented reality (AR) are inspiring content creators and storytellers to develop engaging stories. The European Broadcasting Union (EBU) issued a report on VR / AR (EBU, 2017) stating that 49% of its members are developing or planning to develop immersive content. Members believe that VR offers new opportunities to tell stories from a different perspective and could be more engaging for the audience. In a more recent survey on the industry insights of VR and AR, results show that the interest in VR / AR applications for films and series has dropped since previous surveys (Perkins Coie LLP, 2018). According to the report, this could be due to the belief that shorter experiences work better for AR / VR. However, in the same report, they state that video games sector is still leading the list of the industries with more investment in VR / AR. This seems contradictory, because video games are long audiovisual experiences. Therefore, the reasons behind the drop in investments for VR / AR in audiovisual content other than video games might be different (for example, poor quality of user experience, lack of engaging content or hardware high prices). All in all, these new formats and technologies applied to audiovisual content creation may have an impact on how content is subtitled, and technology should be prepared to face the new challenges.

Academic studies on subtitling technology are limited with a few exceptions (Georgakopoulou, 2012; Díaz-Cintas, 2013, 2014). However, the importance of technology in the practice of subtitling is paramount, as technology is necessary for its existence and further development. Subtitling software has rapidly evolved for the past few years, giving response to this new audiovisual and digital society, which has led to a "technology turn" in audiovisual translation (AVT) and, specifically, in

subtitling (Díaz-Cintas, 2013). Many are the innovations introduced in subtitling software, mainly focused on automation to increase productivity and satisfy the ever-growing need for subtitles in different contexts and situations, as it will be detailed in the next section. Moreover, new audiovisual formats, such as VR or AR, introduce new dimensions and challenges for AVT that need to be tackled by the development of the appropriate technology. To that end, a prototype of a subtitle web editor for 360º videos has been developed in the framework of the European-funded project Immersive Accessibility (ImAc).[1] The main goal of ImAc is to make immersive content accessible to all types of users. To do so, a first step was to develop different technologies to produce the access services for this new medium including subtitles, because according to our research no commercial solutions were available at this point. A first version of a subtitle editor for 360º content has been developed. This prototype has been tested with twenty-seven professional users, with the aim of gathering their feedback regarding the technological needs of subtitlers working with immersive content.

In this article, an overview of current subtitling technology will be offered. Then, the challenges posed by immersive content in terms of subtitling are reviewed. In section 4, the prototype of the ImAc subtitle web editor will be presented and discussed. In section 5, the methodology and the results will be explained. Finally, some conclusions will be drawn.

2. SUBTITLING TECHNOLOGY: OVERVIEW

The change of analogue signal to digital broadcasting, the appearance of DVD and Blu-Ray and the universal access to internet have all contributed to the growth of subtitling and subtitling technology (Díaz-Cintas, 2014). Nowadays, both intralingual and interlingual subtitles are available at the touch of a button for the audience, which has caused what Díaz-Cintas labelled the "commoditisation of subtitling" (Díaz-Cintas, 2013, 2014). The consolidation of digital television and the proliferation of VoD platforms as a mainstream way of consuming audiovisual content and the accessibility approach taken by them, offering subtitles, subtitles for the deaf and hard-of-hearing (SDH), dubbing and audio description in several languages, has given a new

[1] www.imac-project.eu/

boost to audiovisual translation. The demand for digital video content continues to increase and forecasts point to a growth also in media localisation that will become a USD 2.5 billion industry by the end of 2020 (Estopace, 2017). The needs generated by this exponential increase in content and localisation demand will only be met with the support of technology that is able to adapt to the new challenges.

In previous studies, Díaz-Cintas (2013, 2014) offered an extensive review of subtitling technology advances up to that date. From the analogue subtitling practices from the 70s to the digital revolution that brought new advancements to this field, the practice of subtitling has evolved. Nowadays, with the professional software available, subtitlers are able "to create the timecodes, to respect shot changes, to control the reading speed of their subtitles, to translate and spell check their texts, to simulate their subtitles on screen, etc." (Díaz-Cintas, 2013: p. 124). Some examples of professional subtitling software are: EZTitles, FAB, Screen Subtitling, Swift, Spot or WinCAPS. However, the high prices of professional tools favoured the appearance of free software such as Subtitle Workshop, Aegisub or Subtitle Edit. The latter are mostly used by fansubbers to create their own subtitles for the fan community. Díaz-Cintas (2014) distinguishes between fansubs and crowdsourced subtitling. One of the main differences is that fansubbers produce subtitles without the consent of the content owners, and crowdsourced subtitles are distributed with the consent of the interested parties, without copyright infringements. Some platforms that encourage volunteers to create crowdsourced subtitles are Amara, TED or even YouTube. These platforms offer cloud-based subtitling platforms for the volunteers to create subtitles, but with very limited options compared to professional tools. Nonetheless, the trend of cloud-based professional subtitling tools to streamline the creation and distribution of subtitles is noticeable. For example, Zoosubs, imediatrans or OOONA offer an integrated, cloud-based workflow for localising audiovisual content.

The increase of audiovisual content makes subtitling a commodity. Therefore, media companies are continuously looking for solutions to streamline their processes and be able to cope with the growing demand. Subtitling technology includes new features to respond to industry expectations, mainly based on automation. According to Díaz-Cintas (2014), some professional subtitling tools include an automatic detection of shot changes, facilitating the spotting task. Also, most programmes include an audio wave indicator that shows the audio behaviour in the

video. Subtitlers can then skip the parts of the video where the dialogue is missing and go directly to the interest points, especially during quality assurance stage. Also, it is helpful for spotting, because subtitlers can visually see where the subtitle should start and end (Díaz-Cintas, 2014). Speech alignment technology can facilitate the task even more, automatically synchronising the transcription with the soundtrack and the video. Another step forward in automation comes from automatic speech recognition (ASR) software. Some subtitling software, such as Omniscien, can transcribe the audio, extract the dialogue and create a subtitle draft, even in the target language with machine translation (MT) technology (Dranch, 2018).

Several studies have been carried out with the aim of creating live subtitles automatically (Garcia *et al.*, 2009; Álvarez *et al.*, 2010; Mathur *et al.*, 2015). Some technologies that are key to the generation of automatic subtitles are: voice activity detection, ASR, discourse segment detection and speaker diarisation (Álvarez *et al.*, 2010). When this technology is put together in a single system, the creation of machine generated live subtitles is possible. A study on the reception of automatic generated and translated subtitles was carried out by Matamala *et al.* (2015). In the main experiment, thirty participants with different levels of English watched three randomised clips in English: one with no subtitles, one with automatic generated intralingual subtitles and another with automatic generated interlingual subtitles into Spanish. The conclusions of the study showed that intralingual subtitles can be beneficial to increase language comprehension for viewers with a medium level of English (B2). However, interlingual subtitles had a negative impact on C2 level viewers, probably due to a distracting effect.

The necessity of making live events, such as conferences, talks or even lessons, accessible to audiences with hearing impairments has promoted the implementation of ASR systems in several contexts. For example, about 1,500 deaf and hard-of-hearing (HoH) students are an integral part of the campus at the Rochester Institute of Technology. Apart from American Sign Language (ASL) interpreters, they have implemented Microsoft Translate, a communication technology that uses Artificial Intelligence technology to generate subtitles (Roach, 2018). This system uses advanced ASR technology to convert speech into fluent, correctly punctuated text, which can be automatically translated into the 60 languages that the system supports (with the quality that MT currently offers). The deaf and HoH students agreed that this was a useful

tool to complement the ASL interpretation during lessons. Also, professors at Rochester Institute of Technology recognised the potential of this tool for education, because all students (deaf or hearing) used the transcripts as a learning and course material (Roach, 2018). Similar initiatives are being reproduced in other universities, such as the app poliSubs developed by the Universitat Politècnica de València.[2] Previous attempts have also been made at a European level, such as the EU-funded project transLectures[3] (2011-2014), which aimed at developing tools for automatic transcription and translation for online educational videos.

Open and free solutions to generate automatic subtitles with ASR technology can be found in YouTube[4] and the app Web Captioner.[5] YouTube integrates an option to generate automatic subtitles in English, Dutch, French, German, Italian, Japanese, Korean, Portuguese, Russian, and Spanish. When a video is uploaded to YouTube, it can be edited, and transcriptions and translations can be added. Automatic transcriptions with timings are generated and can then be postedited through a basic interface. In the interface, the subtitler can add and delete subtitles, modify the time codes, modify subtitle content, preview subtitles in the video and use the audio wave for a more accurate spotting. A list of keyboard shortcuts is also provided to streamline the process. The transcribed subtitles can be then translated to as many languages as desired and be added to the video. Subtitles generated in YouTube can also be downloaded in different formats (.vtt, .srt, .sbv). Although the quality of the automatic subtitles varies depending on the type of content, the quality of sound, background noises, different accents, etc., this could be a powerful tool to increase accessibility. Web Captioner is a free real-time subtitling app for browsers based on speech-to-text transcription technology. It supports over forty languages and dialects and only a computer with internet connection and a microphone is necessary. Subtitles can be then downloaded in a plain text format .txt or .doc (without time codes).

The use of computer-aided translation (CAT) tools, even if present in many translation fields such as technical or medical translation, is limited in the field of AVT. It is argued that CAT tools are not suitable for AVT

[2] https://www.elmundo.es/comunidad-valenciana/2018/12/26/5c235fdefc6c83_c3018b456e.html
[3] https://www.mllp.upv.es/projects/translectures/
[4] https://support.google.com/youtube/answer/6373554?hl=en
[5] https://webcaptioner.com/

due to the culturally-bound and creative types of content. However, CAT tools are widely used in game localisation (O'Hagan and Mangiron, 2013), which also includes dialogue text to be dubbed and subtitled and creativity and cultural references are involved in the translation process. CAT tools were introduced in game localisation to boost productivity due to the large number of words and the limited time to translate the content. They were also important to maintain consistency across projects where teams of several translators work simultaneously thanks to translation memories (TM) and glossaries integrated in the tools. Consistency and intertextuality are also common and necessary in films and series. Different translators can work in different seasons of the same series without having the reference material. So far, the only way to ensure consistency is to watch previous episodes or look for previous subtitle files, but this could be very time-consuming. Having all the translations in a TM would significantly ease the translator's work. Anticipating industry's needs, some CAT tool companies such as memoQ have introduced some features to facilitate the task of the subtitlers. For example, the tool can process specific subtitle formats such as .srt. Also, the translator can preview the video with the translated subtitles in the same tool with a simple plugin, as can be seen in Image 1.

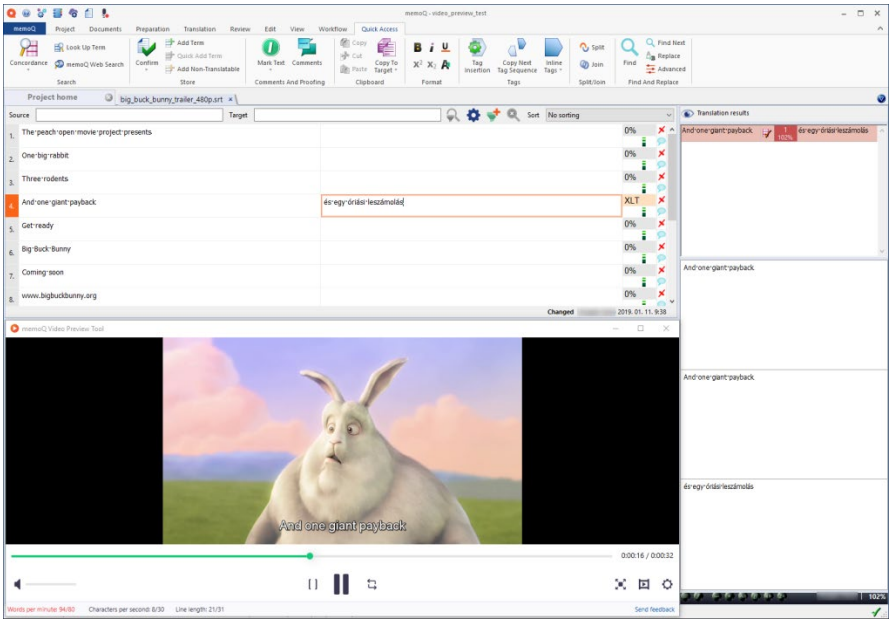


Image 1. memoQ translation panel with video preview.

The next step in automation would be to introduce (MT) in the subtitling workflow. Several funded projects aimed at achieving automatic subtitling with automatic translation have been developed in the last years such as MUSA[6] (2004-2007) and SUMAT[7] (2011-2014). The former's ambitious goal was to create a whole automatic system that converted audio into text, then generated the time-coded subtitles and, finally, translated the subtitles into other languages. However, no tangible results ever materialised (Díaz-Cintas, 2014). The latter's main goal was "to use the archives of subtitle files owned by several subtitling companies to build a large corpus of aligned subtitles that will be used to train SMT [statistical machine translation] systems in various language pairs" (Bywood *et al.*, 2013: p. 596). An evaluation with trained subtitlers was carried out to test the quality of the MT-generated subtitles. Although the study has some limitations, according to their results, "subtitlers considered 56.79% of the subtitles [27,565 MT subtitles] they rated to be of quality 4 or 5, meaning that they required little to no post-editing to be of a publishable standard" (Bywood, Georgakopoulou and Etchegoyhen, 2017: p. 497). Even if results are far from optimal, they should not be disregarded. It is worth noticing that when SUMAT project was developed, the MT system was based on statistical MT and, nowadays, research on the MT field is focused on neural MT, which is the new paradigm for MT (Forcada, 2017). Applying neural MT might result in different results and further research is necessary to clarify the future of MT in AVT.

3. IMMERSIVE MEDIA AND SUBTITLING

Immersive media aim at making the audience feel immersed in a story, as if they were transported to another reality. One example of immersive medium is stereoscopic 3D, which has been present in homes and cinemas in the past few decades. The blockbuster *Avatar* (2009) by James Cameron that was projected in cinemas in stereoscopic 3D all over the world caused a comeback of this technology that was already popular during the 50s (Agulló and Orero, 2017). However, accessibility was

[6] http://sifnos.ilsp.gr/musa/
[7] http://www.fp7-sumat-project.eu/

considered as an afterthought in this medium, and the implementation of subtitles was part of the postproduction stage. Due to that and the lack of specialised subtitling technology for stereoscopic 3D, some issues raised when integrating subtitles. Superimposing 2D subtitles on a 3D image provoked undesirable effects such as ghosting, hindering the readability of subtitles and causing fatigue and eye strain (Agulló and Matamala, 2019).

Other immersive medium still under research and development is AR, which combines real world objects with superimposed virtual objects (Agulló and Matamala, 2019). The applications of this technology are very promising in the field of accessibility, especially in theatres and cinemas. A project led by the researcher Romero-Fresco to use smart glasses to display live subtitling in theatre has been developed by the GALMA Research Group[8] together with the National Theatre in London.[9] They use AR and speech recognition technology to implement live subtitles for their plays. Glasses are adaptable and subtitles customisable.[10] This is an ongoing project and evaluation is still not available, according to our research. If this technology is fine-tuned and mainstreamed, it might become a revolution in accessibility.

Finally, the immersive medium under consideration in this study is VR, specifically 360º videos. This type of content can be watched in head-mounted displays (HMD), giving the viewer the freedom to look around, usually with 180º of freedom in the field of view (FoV). This new format poses different challenges for implementing subtitles. Firstly, unlike in traditional TV / cinema content, the frame for each scene depends on where the viewers decide to look at any moment, so there is no way to guarantee that a specific area of the 360º video is seen by them. Also, the background image where the subtitles will be displayed cannot be foreseen either, which can cause contrast issues and have a negative impact on readability if the subtitles are not well produced. Therefore, one of the main issues that needs to be solved is where to locate the subtitles. Secondly, if the speaker is outside the FoV, this needs to be indicated somehow, to make the content accessible for deaf and HoH viewers as well. And thirdly, the implementation of subtitles must not disrupt the VR experience, that is, subtitles should not break

[8] http://galmaobservatory.eu/projects/captioning-glasses-for-the-national-theatre/
[9] https://www.nationaltheatre.org.uk/your-visit/access/caption-glasses
[10] https://www.youtube.com/watch?v=Hdtf4qUWos4

immersion and should not worsen the VR sickness effect (*i.e.*, viewers feeling dizziness, headache or eye fatigue because of the consumption of VR content).

Some studies have been already carried out regarding implementing subtitles in 360º content (Agulló *et al.*, 2018; Brown *et al.*, 2018; Rothe *et al.*, 2018; Agulló and Matamala, 2019). Some preliminary studies were carried out in order to gather feedback from end-users on how to implement subtitles in 360º contents (Agulló *et al.*, 2018; Agulló and Matamala, 2019). Results from a focus group in Spain showed that end-users would like to receive subtitles as similar as possible as shown in TV content. For example, participants suggested using the current Spanish standard for SDH (AENOR, 2003). They also suggested locating subtitles in a fixed position in relation to the FoV and highlighted the importance of using a black background box in order to avoid readability issues. Regarding providing directions to enhance accessibility, participants suggested including icons (arrows) or text in brackets (to the left, to the right), as well as the possibility to include a compass or radar, in order to indicate where the speaker is located in the 360º video (Agulló and Matamala, 2019). In a different study, a prototype was tested with a limited number of participants in order to gather information on the comfortable field of view for reading subtitles, and the speaker location identification. Also, a new methodological approach for accessibility studies is proposed, based on capabilities instead of disabilities (Agulló *et al.*, 2018). Both in Brown *et al.* and Rothe *et al.*, they compared different subtitling modes in order to evaluate which was the preferred solution. In the first study by the BBC team (Brown *et al.*, 2018), they compared four different modes: (1) Evenly spaced: subtitles equally spaced by 120º in a fixed position below the eye line; (2) Follow head immediately: subtitles follow the viewer as they look around, displayed always in front of them; (3) Follow with lag: the subtitle appears directly in front of the viewer and it remains there until the viewers look somewhere else; then, the subtitle rotates smoothly to the new position in front of the viewer; and (4) Appear in front, then fixed: subtitles appearing in front of viewers, and then fixed until they disappear (in this case, the subtitles do not follow the viewer if they look around). In their study conducted with twenty-four participants, they concluded that the (2) option was the preferred one. In the study by Rothe *et al.* (2018), they tested two types of subtitles with thirty-four participants: static subtitles (that is, subtitles that are always visible in the viewer's FoV) and dynamic subtitles (that

is, subtitles that are in a fixed position close to the speaker). Even if the participants did not state a preference in the comparison part of the questionnaire, dynamic subtitles seemed to have better results in the questions about presence, sickness and workload.

Even if some previous studies have been carried out about the implementation of subtitles in 360º videos, to the best of our knowledge there is currently no specific subtitling software for this type of content, and subtitles so far have been created manually. Therefore, there is a need to develop a subtitling software that responds to the current challenges that have been discussed and that is usable and accessible to professional subtitlers. For that reason, it was decided in the ImAc project to develop a prototype of a subtitle web editor that will be discussed in the following section.

4. IMAC WEB EDITOR

The prototype of the ImAc subtitle web editor has been developed with the aim of producing accessibility services, specifically subtitles, in audiovisual content in 360º. The prototype version of the editor was created following the feedback from professional subtitlers that was gathered in a previous focus group (Agulló and Matamala, 2019). The tool has been developed in a collaboration between the different partners of the ImAc project[11] that includes broadcasters, researchers and technological companies. Specifically, the company Anglatècnic, experts in the engineering and development of software systems for the broadcast and IT sectors, was in charge of the technical development. End-users had a key role in the development, providing valuable feedback from the beginning of the project. It was decided to first develop a light version in web format as a prototype, and a desktop version would be created at a later stage of the project. The prototype editor, which is accessible via browser, supports 360º videos that can be uploaded and then previewed for subtitling. Navigation in the 360º video with the mouse or the keyboard is possible. Most of the options available in the editor are similar to those in other commercial subtitle editors. In Image 2, main options and sections can be seen: video controls (play, stop, pause, forward / backward options, etc.), subtitle controls (style, position of the subtitles, alignment options, colour coding for character identification,

[11] http://www.imac-project.eu/consortium/

actions to navigate the subtitles, buttons for time code in and out, etc.), video preview, subtitle text box, subtitle list, among others.

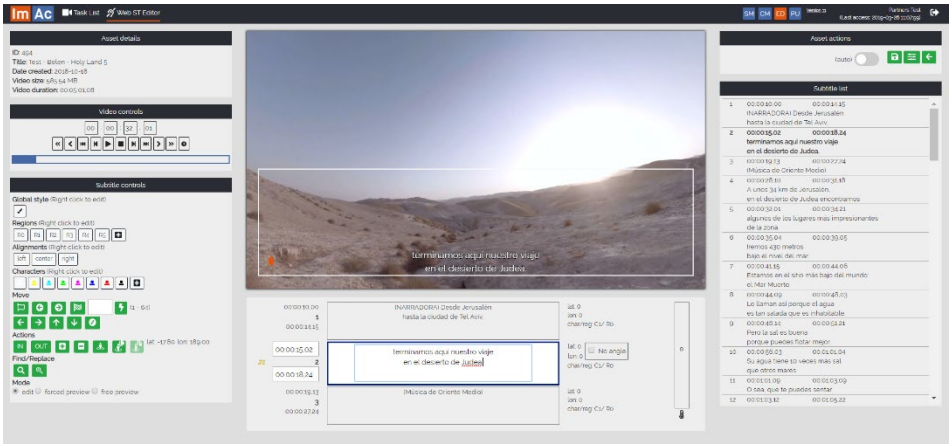


Image 2. ImAc web subtitle editor interface.[12]

The prototype editor also includes a reading speed thermometer for character limitation. The thermometer is a visual guide to avoid exceeding the permitted words per minute. The default parameter is 120 words per minute. The thermometer becomes redder as the subtitles approach the limit. Another option is the pre-set regions. That option allows the subtitler to set different regions for the subtitles (for example, up, down, left, right, etc.). The regions are highlighted with a white rectangle as can be seen in Image 2, so that they can be spotted easily.

Moreover, the prototype editor includes an option that had to be designed due to the nature of 360º content. This option is called "Set current angle". As it has been explained in previous sections, the speakers are not always positioned within the viewers' FoV, because they can move in the 360º space. Therefore, the position of the speaker for each subtitle needs to be indicated when creating the subtitles. To do so, the subtitler can navigate in the video and select the angle where the speaker is positioned. Then, when the option "Set current angle" is activated, the selected subtitle is anchored to the angle where the speaker is positioned. This information will then be translated into a metadata in

[12] The sample video in this image belongs to the video Holy Land (episode 5) created by RYOT.

the subtitle file that will be processed by the 360º video player and, when the speaker is out of the viewers' FoV, a guiding mechanism will appear, for example, an arrow or a radar, to indicate to the viewers where to find the speaker.

Finally, it is worth mentioning that the prototype editor includes three preview modes: (1) Edit mode: for editing the subtitles; (2) Forced preview: for previewing the subtitles (edit options are blocked) with the system forcing the selected angle for each subtitle; and (3) Free preview: for previewing the subtitles (edit options are blocked), being free to navigate the video as desired.

5. EVALUATION

An experiment to test the prototype version of the ImAc web subtitle editor was conducted. The goal of this experiment was to test the usability of the editor and, most importantly, to gather participants' feedback on the tool and on their needs when subtitling 360º content. Before carrying out the present test, a pilot was conducted with three users (one practitioner, one university lecturer and one engineer) to verify that the methodology worked properly. Pilot participants took the test online, timed themselves and provided feedback to the researcher. This section describes the evaluation methodology and presents the obtained results.

5.1. Evaluation setup

The test was carried out online and each participant took the test with their personal computers / laptops. The only technical requirements were to have a stable, high speed internet connection and to access the web editor with Google Chrome (recommended) or Firefox. The web editor includes a content management module that was used to set up the entire test. In the content management tool, users with the role of subtitler (for example, P1, P2, P3, etc.) were created and assigned to each participant. Also, each participant was assigned an individual task for subtitling the same sample video. The video and the task were copied as per the number of participants, so they had access to an individual task only accessible by each of them. The videos were uploaded in low resolution to avoid overloading the server, causing poor performance. The login information was provided by email to participants, together

with the instructions. Questionnaires were administered using Google Forms. The test was designed in English, including the video to be subtitled, the instructions and the questionnaires.

5.2. Evaluation methodology

The test was sent to participants via email. It was divided into three parts and participants were required to complete it in just one session:

(1) Introduction, ethical clearance and demographic questionnaire

In the first part of the test, context information about the ImAc project, the goal of the test, the estimated duration (30 minutes) and the participant code was provided in the email to participants. Then, they were asked to give their consent to participate in the test via digital form, as requested by the ethics committee at Universitat Autònoma de Barcelona. Finally, they needed to fill in a demographic questionnaire in order to gather data about their profile, as will be reported in section 5.4.

(2) Technical information and instructions

In this second part of the test, the participants were asked to first read a quick user guide that was created bespoke for the test. It was decided that a user guide would be provided, instead of letting them figure out how the editor worked, because it was assumed that most participants were not familiar with 360º videos, nor with the potential issues of subtitling this type of content.

In the user guide, an emphasis was placed on the "Set the current angle" option, because this was the newest feature and the most difficult to understand, compared to current subtitling software. Also, giving participants more information about the tool would speed up the tasks and elicit more comprehensive and valuable replies in the open questions part of the test.

Then, instructions on how to access the web editor, as well as login information were provided. A transcription for the video was also provided to speed up the process. The tasks to be carried out were clearly written and shared with the participants as well, and were as follows:

The tasks that we kindly ask you to perform are:

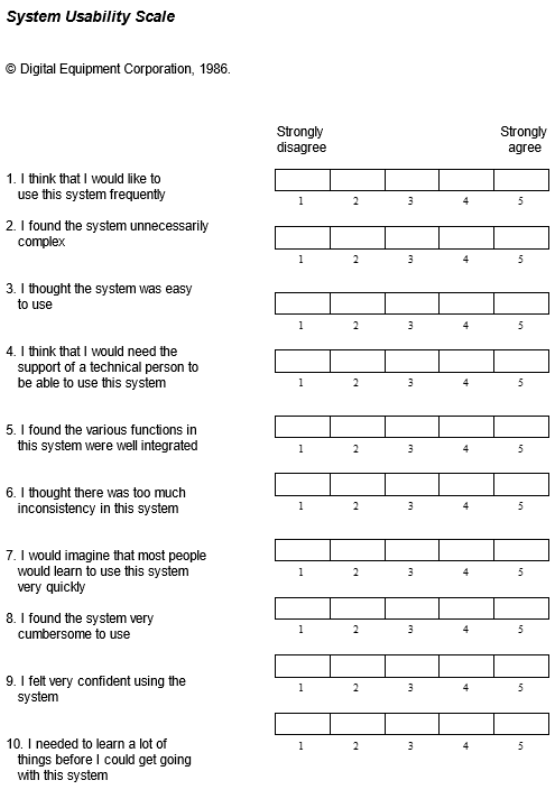
1. Go to the subtitle editor using the login information. To access the subtitle web editor, you have to go to this address: XXXX and enter the login info that has been provided to you in the email.
2. Open the video that has been assigned to you for subtitling.
3. Subtitle the video into your native language from 00:00:00 to 00:01:11.
    a. Add subtitles with the correct timecodes.
    b. Assign the different colours to the different characters in the video.
    c. Set the angle for each subtitle.
    d. Set a second region for subtitles and apply it to one subtitle.
    e. Change the alignment to the left for one subtitle.
    f. Insert a subtitle between two existing subtitles.
    g. Delete two subtitles.
    h. Look for a subtitle by content.
4. Preview the video with the forced mode.
5. Save the subtitles and go back to the main window.
6. Open the video again.
7. Preview the video with free mode.
8. Save the subtitles and go back to the main window.

(3) Evaluation questionnaires

After performing all the tasks, participants were asked to reply to an online questionnaire that was divided into two parts: System Usability Scale (SUS) questionnaire and open questions.

Testing user experience is a widely researched field of study (Goodman *et al.*, 2012; Tullis and Albert, 2013; Pannafino and McNeil, 2017). There are several methods to test user experience in relation to effectiveness, efficiency and satisfaction. For example, cognitive walkthroughs, card sorting, icon usability testing, contextual inquiry or online surveys. In this test, the main focus is on usability as defined by Brooke (1996: 1): "Usability is not a quality that exists in any real or absolute sense. Perhaps it can be best summed up as being a general quality of the appropriateness to a purpose of any particular artefact." In

this sense, the appropriateness of the prototype of ImAc web editor for subtitling 360º content was tested. For that purpose, one of the widest known and used scales, namely the System Usability Scale (SUS), was administered to participants. SUS is a ten-item Likert scale. Each item needs to be assessed from 0 to 5. This scale was chosen because it is easy to administer, provides reliable results with small sample sizes, and has been validated and used in many studies as a standard self-reported metrics (Brooke, 2013), becoming one of the most popular measurements for usability testing (Lewis, 2018).



System Usability Scale

© Digital Equipment Corporation, 1986.

	Strongly disagree				Strongly agree
1. I think that I would like to use this system frequently	1	2	3	4	5
2. I found the system unnecessarily complex	1	2	3	4	5
3. I thought the system was easy to use	1	2	3	4	5
4. I think that I would need the support of a technical person to be able to use this system	1	2	3	4	5
5. I found the various functions in this system were well integrated	1	2	3	4	5
6. I thought there was too much inconsistency in this system	1	2	3	4	5
7. I would imagine that most people would learn to use this system very quickly	1	2	3	4	5
8. I found the system very cumbersome to use	1	2	3	4	5
9. I felt very confident using the system	1	2	3	4	5
10. I needed to learn a lot of things before I could get going with this system	1	2	3	4	5

Image 3. System Usability Scale (Brooke, 1996).

To complement the quantitative data from SUS, open questions were also included in the post-questionnaire. The questions were aimed at gathering qualitative information on participants' feedback and impressions on the prototype and its specific functionalities. The questions were:

1. What did you like most about the subtitle editor?
2. What did you like least about the subtitle editor?
3. What do you think could be improved, and how?
4. Did you miss any functionality? If yes, can you tell us which?
5. Do you find the feature for setting the angle for the subtitle easy to use? Explain why.
6. Were the preview modes useful for you? Explain why.
7. Do you think it will take you longer to subtitle videos in 360º? Why?
8. Do you think 360º videos will impact your work as a subtitler?
9. Other comments.

5.3. Participants

Twenty-seven participants took part in the current study. The recruitment criterion was that participants had to be subtitlers who professionally subtitle audiovisual content. They were recruited via personal contacts and also by email and public posts on Twitter. The test was designed in English so that professionals from different countries could participate without language being a major limitation. The source language of the video was English. Participants could choose the language into which they preferred to create the subtitles. The quality of the subtitles was not observed; therefore, the participants did not need to master the target languages.

5.4. Evaluation results

The results from the different questionnaires are reported in this subsection.

Demographic questionnaire

Twenty-seven participants took part in the test (twenty females and seven males), with ages ranging 24-48 (mean=35.6, sd=6.9). Their main languages (that is, mother tongue) were Spanish (19), Catalan (3), English (3), Polish (2), Basque (1), Croatian (1) and Romanian (1) (two participants were bilingual Spanish / Catalan and one participant was bilingual Spanish / Basque). They describe their main jobs as AVT translators, subtitlers for different kind of products, university lecturers

and researchers. Only one participant has subtitled a 360º video before. They presented a varying experience in the field of subtitling, varying from 1 month to 20 years (mean=8.1; sd=6.1). sixteen participants have produced more than 300 hours of subtitled content, three participants have produced between 151 and 300 hours of subtitled content, four participants have produced between 51 and 150 hours and four participants have produced less than 50 hours. Participants usually subtitle in Spanish (21), English (10), Catalan (4), Polish (2), Basque (1), Croatian (1), French (1), Italian (1) or Romanian (1). Participants declared using different subtitling software (FAB, WinCAPS, Aegisub, VisualSubSync, Subtitle Workshop, EZTitles, Swift, Subtitle Edit, TED, Amara, YouTube, Spot, VICOM, Jayex, proprietary software from clients, among others). Twenty-six participants have studies of university level and one participant has further education. Eighteen participants have a degree or master's degree in translation and interpreting studies (or languages degrees), eight of them have PhD studies and nine of them specialise in Audiovisual Translation. Twenty-four participants have received specialised training on subtitling in MAs, specialised courses or training.

When asked about which devices they used on a daily basis, all participants indicated that they use mobile phones; twenty-three participants use laptops; twenty-one participants use TVs, seventeen participants use PCs; and nine of them use tablets. When asked about how often they watch virtual reality content, none of the participants have watched VR content on a tablet, twenty-three participants have never watched VR content on a smartphone connected to HMD or in HMD; some (fourteen) occasionally watch VR content on a smartphone, twelve participants on a PC, four on a smartphone connected to HMD and three in HMD; one participant watches VR content on a PC at least once a month, and one participant on a HMD; finally, one participant watches VR content on a smartphone at least once a week. When asked to explain why they have never used virtual reality content such as 360º videos or only occasionally, three participants replied that they are not interested, four participants replied that it is not accessible, sixteen participants replied that they have not had the chance to use it, and others gave other reasons regarding the expensive price, difficulties to use the technology or the lack of appealing content. When asked to state their level of agreement with the statement "I am interested in virtual reality content (such as 360º videos)", three participants replied that they

strongly agreed, thirteen replied that they agreed, seven that they neither agreed nor disagreed and four of them disagreed. Finally, when asked if they own any device to access virtual reality content, fifteen participants replied that they do not own any, five replied that they do not know or prefer not to reply and seven replied that they do (including BOBVR Z4, HTC Vive, PC, laptop, smartphone and PlayStation VR).

SUS

SUS scoring system is standardised and defined by its creators. It is considered that a score above 68 is above average and below 68 would be below average. The raw SUS score for this test was 59.5. The letter grade is D+, and the score corresponds to the percentile rank: 29-30% (Sauro and Lewis 2016: pp. 203-204). The result could also be due to the lack of experience subtitling 360º content. However, this was a first prototype, so the most important part of the present study was the qualitative feedback that will be detailed below and that provides valuable input on how to improve this first version of the 360º video subtitle editor.

SUS statements	1 (strongly disagree)	2	3	4	5 (strongly agree)
1. I think that I would like to use this system frequently	3 (11.1%)	4 (14.8%)	11 (40.8%)	8 (29.6%)	1 (3.7%)
2. I found the system unnecessarily complex	5 (18.5%)	10 (37.1%)	7 (25.9%)	4 (14.8%)	1 (3.7%)
3. I thought the system was easy to use	1 (3.7%)	6 (22.2%)	4 (14.8%)	14 (51.9%)	2 (7.4%)
4. I think that I would need the support of a technical person to be able to use this system	8 (29.6%)	12 (44.5%)	5 (18.5%)	0 (0%)	2 (7.4%)
5. I found the various functions in	0 (0%)	6 (22.2%)	9 (33.3%)	10 (37.1%)	2 (7.4%)

this system were well integrated					
6. I thought there was too much inconsistency in this system	4 (14.8%)	10 (37.1%)	11 (40.7%)	2 (7.4%)	0 (0%)
7. I would imagine that most people would learn to use this system very quickly	2 (7.4%)	2 (7.4%)	7 (30%)	8 (29.6%)	8 (29.6%)
8. I found the system very cumbersome to use	2 (7.4%)	5 (18.5%)	8 (29.6%)	10 (37.1%)	2 (7.4%)
9. I felt very confident using the system	0 (0%)	8 (29.6%)	8 (29.6%)	11 (40.8%)	0 (0%)
10. I needed to learn a lot of things before I could get going with this system	9 (33.3%)	3 (11.1%)	10 (37.1%)	4 (14.8%)	1 (3.7%)

Table 1. SUS replies from participants.

Open questions

The analysis of replies to open questions follows a qualitative approach. Participants were asked to reply with their own words to the questions specified in section 5.2. All replies were thoroughly revised and tagged. Some of the questions were generic aimed at gathering general feedback on the ImAc web editor and others were more specific about functionalities. Finally, some questions were aimed at gathering feedback on how subtitlers perceived that the subtitling task could be impacted by immersive environments. The analysis allowed to define different areas that work well and others that need to be improved in the current ImAc editor, how the new functionalities were received and subtitlers' feedback on the future practice of subtitling immersive content. The most relevant aspects are described below.

(1) General feedback on web editor

As stated before, the open questions for the general feedback on the prototype were focused on what participants liked about the tool, what they did not like and what they would improve. After analysing the results, it can be stated that the prototype of the 360º subtitle editor was well received due to several reasons. Participants stated that what they liked the most was that the system and some of its features were easy to use (the word "easy" was used in nine of the replies). Also, adjectives such as intuitive (2), user-friendly (1) and straightforward (1) were used to describe the tool, as well as characteristics such as simplicity (1), practicality (1) and versatility (1). The interface was referred to by some respondents (4) as a positive part of the web editor, considered clear and well designed. Some of the functions that were more praised and are related to the specific task of subtitling 360º content were: navigation and subtitling of 360º videos (5), set the angle option (4), assigning pre-set regions (4), assigning colours to different speakers (3) and reading speed thermometer (2). Two respondents stated that they liked the tool was cloud-based. Therefore, the main innovations introduced in this prototype such as preview and navigation of 360º content and setting the angle for the speakers can be considered usable.

As for improvable features, two main blocks were detected: (a) general subtitling features and (b) specific 360º content subtitling features. The first block is less relevant for the current study, because the tested version was a prototype and general features were planned to be improved in future versions. The second block, however, is important to redefine the needs of subtitlers regarding 360º videos that might have not been considered when developing the tool. Regarding the first block, several improvements were suggested: customisable shortcuts; improved and clearer time coding options; freedom to break lines as desired (at the time the test was carried out, an automatic segmentation based on a default character limitation was implemented, not allowing customisation); transparency in the reading speed thermometer and clearer information about characters per second (cps) or words per minute (wpm); sound wave to ease spotting; more editing options for subtitles (including bold, italics, different colours); more quality assurance options such as spellcheck; among other minor suggestions.

In the second block, some interesting comments for improvement were spotted for the 360º content subtitling features. Firstly, two participants suggested to integrate editing and preview modes. Instead of

changing from edit to preview mode each time the subtitler needs to preview their work, participants would prefer to have it integrated in a unique mode as in other 2D subtitling editors. This suggestion could ease the spotting process and quality assurance. Secondly, regarding the set the angle option, one participant suggested that it would be easier to right click on the video with the mouse to indicate where the speaker is or select with the mouse the area where the speaker is, instead of navigating with the mouse or arrows. This suggestion could improve accuracy for this feature. Finally, two respondents suggested to include an automatic shot detection system. However, this suggestion is not compatible with 360º videos. As stated before, the viewer is in control of the camera for this type of content. Therefore, the changes of shots depend on viewers and are unpredictable. Automatic shot change options are not relevant in subtitling for immersive content.

(2) Specific functionalities

The second part of the open questionnaire was addressed to specific functionalities for 360º content: the "set the angle" option and the preview modes. Regarding the "set the angle" option, most participants (20) considered it was easy to use, describing the option as easy or very easy, relatively simple, straightforward, not complex, intuitive and logical. Five users, though, found it difficult. No correlation was found between previous experience or knowledge of immersive environments for this negative reply. Participants also made some recommendations to improve this option. Three of them suggested to have an option to apply the same angle to consecutive subtitles. This would definitely ease the task of assigning an angle for each character and scene. Also, one subtitler raised a concern about off-screen speakers (for example, a narrator), in which case no angle should be chosen. This was not considered when developing the tool, as it was assumed that the speaker was always on screen, but it is not always the case. Therefore, an option for indicating off-screen voices without angle needs to be implemented.

As far as the preview modes, most participants (23) considered these modes useful. Three participants stated that forced mode was useful to check the subtitling work and the free mode was useful to observe the subtitles as a final user would do. Four participants considered it necessary to integrate edit and preview modes, so that they can edit subtitles while previewing the video.

(3) Impact of subtitling 360º content

The last part of the open questionnaire was aimed at gathering general feedback about the professional subtitlers' impressions on this new medium and subtitling practice. When asked whether subtitling 360º video will take longer, most participants (22) responded affirmatively, and most of them (16) considered that having to set the angle would be more time-consuming. Two participants also stated that subtitling 360º would take longer, because the subtitler needs to check the whole 360º video in case there are some texts on screen or inserts that need to be translated in the subtitle. Three participants considered that it should not take longer as long as subtitlers have access to specific software for it. Finally, one participant was worried about shot changes and how they would work in 360º. As it has been stated before, this is not relevant in 360º videos.

When participants were asked about the impact of subtitling 360º videos on the job of a subtitler, different opinions were expressed. Three participants believed that 360º video will have no impact on the subtitler profession and five were not sure about it. Six participants thought that this will have an immediate impact on the profession and most of them (9) considered that 360º videos will impact subtitling, but in the future, if this medium is mainstreamed and the demand increases.

7. CONCLUSIONS

An updated review of current subtitling technology has been presented in this article in order to contextualise the study. Different innovative solutions are being developed to cope with current subtitling demands as the audiovisual translation industry grows, due to the digitalisation of communication and proliferation of VoD platforms. Efforts are put into automating and streamlining the workflow of subtitling, with technologies such as ASR, CAT tools or MT. However, new challenges for subtitling are being posed not only by the increasing demand but also by the appearance of new media, such as immersive environments. A review of main immersive environments (3D, AR and VR) and their implications for subtitling has also been introduced in this article. The focus of the study is on VR and, therefore, the main challenges of subtitling 360º content have been presented. Professional

subtitlers now need to consider new aspects such as where to locate the subtitles for an optimal reading or how to indicate when a speaker is outside of the FoV of the viewer. To that end, a prototype of the ImAc web editor has been developed and presented to twenty-seven professional subtitlers who have tested the tool and reported the correspondent feedback on usability and preferences.

The test has shed some light on the possibilities of subtitling 360º content as well as the most important characteristics that a subtitling software should include to be usable for that task. New features designed considering the nature of 360º videos such as setting the angle, pre-set regions or preview modes have been well received by most participants. According to their feedback, these features are usable and suitable to generate subtitles for this kind of content, although some improvements have been suggested and will be implemented in future versions of the editor. For example, the integration of the edit and preview mode or easing the task of setting the angle or including an option for off-screen characters. Also, it is important to remark that traditional subtitling considerations such as shot changes do not apply in this new medium. Therefore, automatic shot changes options will not need to be implemented in this type of subtitle editors. As reported in the results section, most participants believe that this new medium will have an impact on the subtitling practice, mainly because of the new dimension brought by it: directions. Having to set the angle for the different speakers and having a 360º sphere to look around seems to concern subtitlers. Therefore, the technology provided for this task needs to focus on simplifying and automating these additional tasks to make the subtitling process easier.

Some limitations were identified in this test. The estimated duration of the test was not accurate. When the pilot for the test was carried out, pilot participants informed that the test would take around 30 minutes, but then this time was considered insufficient by some of the participants. This does not mean that participants had to stop the test, but some of them were frustrated that the estimation was not accurate enough. For future tests of this type, the duration should be longer, or participants should perform a previous session to get use to the tool before carrying out the test. Another limitation was the profile of subtitlers. Some subtitlers (especially for interlingual subtitles) are used to translating templates, not generating subtitles from scratch. Therefore, some of them might not be used to the process of setting timings, which was considered

time-consuming and difficult by some participants. However, the participants of this test were familiar with subtitling software, because they replied to the question "What software do you normally use?" as reported in the demographic results section. For future tests, if possible, all participants should be accustomed to generating subtitles from scratch or at least a question in the demographic questionnaire should be included in this regard in order to find whether this has a correlation with the results or not.

This study has proven the importance of carrying out usability tests with end users when developing specific software. Subtitlers' feedback has been essential to define the future of the ImAc editor and to develop a tool that would respond to professional needs and market demands. Future versions should be again tested and polished until professional subtitlers are satisfied with the results. Subtitling is a powerful tool for accessing information and is becoming an intrinsic part of the audiovisual communication. Therefore, the necessity to have appropriate software and technology to respond to the increasing demands is clear. A subtitling revolution will never be achieved without a revolutionary technology that complements it and subtitlers are the cornerstone of this revolution.

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REFERENCIAS BIBLOGRÁFICAS

Agulló, Belén and Anna Matamala (2019), "The challenge of subtitling for the deaf and hard-of-hearing in immersive environments: results from a focus group", *The Journal of Specialised Translation*, 32, pp. 217-235, on https://jostrans.org/issue32/art_agullo.pdf (consulted 22/12/2020).

Agulló, Belén and Pilar Orero (2017), "3D Movie Subtitling: Searching for the best viewing experience", *CoMe-Studi di Comunicazione e Mediazione linguistica e culturale,* 2, pp. 91-101.

Agulló, Belén, Anna Matamala, and Pilar Orero (2018), "From disabilities to capabilities: testing subtitles in immersive environments with end users", *HIKMA,* 17, pp. 195-220. DOI: https://doi.org/10.21071/hikma.v17i0.11167.

Álvarez, Aitor, Arantza del Pozo and, Andoni Arruti (2010), "APyCA: Towards the automatic subtitling of television content in Spanish", en Maria Ganzha, Marcin Paprzycki (eds.) *Proceedings of the International Multiconference on Computer Science and Information Technology*, Danvers, MA, IEEE, pp. 567-574, on https://ieeexplore.ieee.org/document/5680055 (source consulted 22/12/2020) . DOI: https://doi.org/10.1109/IMCSIT.2010.5680055.

Asociación Española de Normalización y Certificación (AENOR) (2003), *Norma UNE 153010: Subtitulado para personas sordas y personas con discapacidad auditiva. Subtitulado a través del teletexto*. Madrid: Asociación Española de Normalización y Certificación.

Brooke, John (1996), "SUS-A quick and dirty usability scale", in Patrick W. Jordan *et al.* (eds.), *Usability evaluation in industry*, London, Taylor and Francis, pp. 189-194.

Brooke, John (2013), "SUS: A Retrospective", *Journal of Usability Studies*, 8(2), pp. 29-40.

Brown, Andy, Jayson Turner, Jake Patterson, Anastasia Schmitz, Mike Armstrong, and Maxine Glancy (2018), "Exploring Subtitle Behaviour for 360° Video." *White Paper WHP 330*, BBC Research & Development, on https://www.bbc.co.uk/rd/publications/whitepaper330 (consulted 26/3/2019).

Bywood, Lindsay, Martin Volk, Mark Fishel, and Panayota Georgakopoulou (2013), "Parallel subtitle corpora and their applications in machine translation and translatology", *Perspectives*,

21(4), pp. 595-610. DOI: https://doi.org/10.1080/0907676X.2013.831920.

Bywood, Lindsey, Panayota Georgakopoulou and Thierry Etchegoyhen (2017), "Embracing the threat: machine translation as a solution for subtitling", *Perspectives*, 25(3), pp. 492-508. DOI: https://doi.org/10.1080/0907676X.2017.1291695.

Díaz-Cintas, Jorge (2013), "The technology turn in subtitling", in Marcel Thelen and Barbara LewandowskaTomaszczyk (eds.), *Translation and Meaning: Part 9*, Maastricht, Zuyd University of Applied Sciences, pp. 119-132.

Díaz-Cintas, Jorge (2014), "Technological Strides in Subtitling", in Chan Sin-wai (ed.), *The Routledge Encyclopedia of Translation Technology Routledge*, Abingdon, UK, Routledge, pp. 632-643.

Dranch, Konstantin (2018), "Translation tech goes media: Subtitling and dubbing won't stay uncontested for long", *Nimdzi Blog*, on https://www.nimdzi.com/translation-tech-goes-media/ (consulted 18/1/2019).

Estopace, Eden (2017), "Audiovisual Translation Hits a Sweet Spot as Subscription Video On-Demand Skyrockets", *Slator*, on https://slator.com/features/audiovisual-translation-hits-sweet-spot-subscription-video-on-demand-skyrockets/ (consulted 15/1/2019).

European Broadcasting Union (EBU) (2017), "Virtual Reality: How are public broadcasters using it?", on https://www.ebu.ch/publications/virtual-reality-how-are-public-broadcasters-using-it (consulted 11/1/2019).

Forcada, Mikel L. (2017), "Making sense of neural machine translation", *Translation Spaces*, 6(2), pp. 291–309. DOI: https://doi.org/10.1075/ts.6.2.06for.

Garcia, Jose Enrique, Alfonso Ortega, Eduardo Lleida, Tomas Lozano, Emiliano Bernues, and Daniel Sanchez (2009), "Audio and text synchronization for TV news subtitling based on Automatic Speech

Recognition", *2009 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting*, Piscataway, NJ, IEEE, pp. 1-6. DOI: https://doi.org/10.1109/ISBMSB.2009.5133758.

Georgakopoulou, Panayota (2012), "Challenges for the audiovisual industry in the digital age: the everchanging needs of subtitle production", *The Journal of Specialised Translation*, 17, pp. 78-103.

Goodman, Elizabeth, Mike Kuniavsky and Andrea Moed (2012), *Observing the User Experience: A Practitioner's Guide to User Research*, San Francisco, CA, Morgan Kaufmann.

Harris, Aisha, Margaret Lyons, and Maureen Ryan (2019), "'Bandersnatch' Has Many Paths, but Do Any of Them Add Up to Anything?" *The New York Times*, Jan. 4, on https://www.nytimes.com/2019/01/04/arts/television/bandersnatch-black-mirror-netflix.html (consulted 11/1/2019).

Lewis, James R. (2018), "The System Usability Scale: Past, Present, and Future", *International Journal of Human-Computer Interaction*, 34(7), pp. 577-590. DOI: https://doi.org/10.1080/10447318.2018.1455307.

Matamala, Anna, Andreu Oliver Moreno, Aitor Álvarez Muniain and Andoni Azpeitia Zaldua (2015), "The reception of intralingual and interlingual subtitling: an exploratory study within the HBB4ALL project", *Proceedings of the 37th Conference Translating and the Computer*, pp. 12-17, in https://ddd.uab.cat/record/144868 (consulted 11/1/2019).

Mathur, Abhinav, Tanya Saxena, and Rajalakshmi Krishnamurthi (2015), "Generating Subtitles Automatically Using Audio Extraction and Speech Recognition", *2015 IEEE International Conference on Computational Intelligence & Communication Technology*, Ghaziabad, India, IEEE, pp. 621-626, on http://www.proceedings.com/25890.html (consulted 22/12/2020). DOI: https://doi.org/10.1109/CICT.2015.46.

Morales, Manuel, Tommaso Koch, and Luis Pablo Beauregard (2019), "Netflix removes Castilian Spanish subtitles from Alfonso Cuarón's 'Roma'", *El País*, October 1st, https://elpais.com/elpais/2019/01/10/inenglish/1547125380_758985.html (consulted 11/1/2019).

O'Hagan, Minako and Carme Mangiron (2013), *Game Localization: Translating for the Global Digital Entertainment Industry.* Philadelphia, John Benjamins. DOI: https://doi.org/10.1075/btl.106.

Pannafino, James and Patrick McNeil (2017), *UX Methods: A Quick Guide to User Experience Research Methods*, CDUXP LLC.

Perkins Coie LLP (2018), "2018 Augmented and Virtual Reality survey report: Insights into the future of AR/VR", on https://www.perkinscoie.com/images/content/1/8/v2/187785/2018-VR-AR-Survey-Digital.pdf (consulted on 11/1/2019).

Roach, Joan (2018). "AI technology helps students who are deaf learn", The AI Blog, on https://blogs.microsoft.com/ai/ai-powered-captioning/ (consulted on 29/1/2019).

Rothe, Sylvia, Kim Tran and Heinrich Hussmann (2018), "Dynamic Subtitles in Cinematic Virtual Reality", *Interactive Experiences for Television and Online Video (ACM TVX) 2018*, ACM, on https://tvx.acm.org/2018/ (consulted on 22/12/2020). DOI: https://doi.org/10.1145/3210825.3213556.

Sauro, Jeff and James R. Lewis (2016), *Quantifying the User Experience: Practical Statistics for User Research*. Amsterdam, Morgan Kaufmann. DOI: https://doi.org/10.1016/B978-0-12-802308-2.00002-3.

Tullis, Thomas and William Albert (2013), *Measuring the User Experience: Collecting, Analyzing, and Presenting Usability Metrics*, Burlingtom MA, Morgan Kaufmann.