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Electroencephalographic beta coherence as an objective measure of psychological immersion in film

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Abstract

All audiovisual translation (AVT) modes mediate the audiovisual text for the audience. For audiences excluded from all or part of a visual or an auditory channel, this has significant implications in terms of comprehension and enjoyment. With subtitling (SDH in particular), we want the audiences to have the same quality of access to the characters and worlds that is afforded the hearing audience. Likewise, with AD, we want the audiences to have an equivalent experience to that afforded sighted audiences. Since the degree to which an audience becomes immersed in the story world plays an important role in this quality of access and enjoyment, it would be useful to find ways to measure immersion reliably. In this article we present a discussion on the measurement of immersion in subtitled film using a triangulation of offline and online measures. In particular, electroencephalography (EEG) as an online measure holds a lot of potential in AVT research. We present the results of a pilot study in which EEG beta coherence between the prefrontal and posterior parietal cortices is used as an indication of the degree to which an audience surrenders itself to the story world and experience the characters and events imaginatively in an immersed state. Our findings indicate that EEG beta coherence could be a valuable tool for measuring the fluctuating states of immersion in film in the presence of subtitles, but also potentially in the context of AD.

Keywords

Electroencephalography (EEG); immersion; audio description (AD); subtitling; cognition; online measures; offline measures; audiovisual translation (AVT).

1. Background

In the subtitling of a fiction film, as in other modes in AVT like AD, one of the main goals is to preserve the aesthetic impact of the film - to allow the audience excluded from the auditory channel the same opportunity to lose themselves in the story as that awarded to a hearing audience. The impact of a film is incredibly difficult to measure and to replicate due to the many elements that are woven together in this dynamic and polysemiotic text.

As a result of the complexity of the audiovisual text, it makes various demands on the cognitive capacity of the audience. Hearing and sighted viewers have to process verbal and non-verbal information that is presented in both auditory and visual channels simultaneously. And then we complicate this text even further by adding subtitles or AD for audiences who are excluded from part of the text for linguistic or physical reasons.

In terms of visual processing, we know by now that subtitles affect viewing behaviour. Some viewing behaviour is automatic (bottom-up processing), and not under conscious control, such as looking at movement or contrast, looking at the centre of the screen, looking at faces, mouths, eyes, and looking at on-screen text. But some viewing behaviour is a conscious activity, like reading (top-down processing). In this paper, we will look at the tension between top-down and bottom-up processing of text on video. We will also consider the complexity of measuring competing sound sources.

Various studies have indicated that text is processed automatically (see d'Ydewalle and Van Rensbergen, 1989; d'Ydewalle, Praet, Verfaillie, and van Rensbergen, 1991; d'Ydewalle and De Bruycker, 2007). There is also evidence that subtitles are processed effectively by viewers (see, e.g. Perego *et al*., 2010). It has been established that subtitled film does not impact the viewer experience negatively (see Kruger, Soto-Sanfiel, Doherty and Ibrahim, 2016). Adding English same-language subtitles actually improves the immersion of viewers in terms of transportation, especially for viewers watching the program in their second language. What we are particularly interested in, is therefore to find a way of measuring immersion online, in order to track the fluctuations in immersion according to different scene types.

2. Film and narrative

Before discussing the measurement of immersion using online measures such as EEG, it may be useful to pause a moment to reflect on the nature of film, and on the ways film manage to draw the audience into a fictional world. In semiotic terms we could say that film is iconic. It presents "a heterocosm which resembles real life", according to Mainar (1993). According to Carroll and Seeley (2013), we use similar cognitive tools to process film and reality, drawing on schemas and "recognitional prompts" that are established over time. In other words, a lot of what we do when we engage with real and fictional realities is filling in gaps, predicting, assuming continuities even when these are absent. For the blind audience this is no different, as they have to rely on the interpretation of contextual sounds supplemented by dialogue and AD.

When we are experiencing a fiction film, we make sense of the narrative through what could be termed narrativisation. We project ourselves into the fictional reality, interpreting, experiencing and co-creating the narrative (as AVT practitioner or as audience member). We experience fictional events as though we are living them, using the same cognitive tools. We experience fictional characters as though we are in their shoes, posturing as them, imposing on their world as though we were them.

According to Gallese (2009) and Gallese and Guerra (2012), there is a continuity between the film and the viewer that is known as embodied simulation; actions, emotions and sensations of others being mapped onto the observer's sensory-motor and viscera-motor neural representations. According to Tversky and Hard (2009) we take allocentric perspectives when we witness populated scenes - an act that results in disembodied cognition. This means that, deictically, we assume hypothetical positions outside ourselves. How, then, does subtitling and AD impact on this experience? Both modes are in essence extradiegetic (originating outside the story world and outside the awareness of the characters). Subtitles pose graphic interference, and AD auditory interference; both causing split attention.

The experience of disembodied cognition means that the audience engages with the fictional world to such an extent that they have the sense of experiencing that world, of being transported into that reality for the duration of the film. This sensation can be called immersion.

3. Immersion

Immersion is the sensation of viewers being transported into the story world, being swept up in this world to such an extent that it takes priority over their experience of their immediate surroundings. But fictional immersion is a delicate cognitive state. The audience is drawn into a virtual reality in which they experi-

ence the fiction created by the film as though they had a position much closer to the action than they actually have. This willing suspension of disbelief is central to the enjoyment of film, as indeed it is to the enjoyment of written narratives.

Immersion could be considered an umbrella term for the related concepts of presence, transportation, engagement, flow, and similar terms. Presence refers to the sensation users of devices like computers or virtual reality have of being present spatially in a mediated environment, and therefore not present in their physical location (Wissmath, Weibel, and Groner, 2009). Transportation is a related concept that refers to the viewer being plunged (immersed) into the fictional world of film or fiction by suspending the facts of the real world around them (i.e. losing awareness of others in the room, the chair you are sitting on, etc.). Green and Brock (2000; 2002) and Green, Brock and Kaufman (2004) used the concept extensively in the study of narrative, also combining it with character identification and enjoyment. Tal-Or and Cohen (2010) approached audience involvement in film in particular by looking at identification and transportation.

In AVT, immersion has been studied in the context of AD and radio drama by Fryer and colleagues (Fryer and Freeman, 2012; 2014; Fryer, Pring and Freeman, 2013) sound effects as well as by Wilken and Kruger (2016), and Kruger, Soto-Sanfiel and Doherty (2017). In the latter study it was established that viewer immersion and visual attention in film varies considerably depending on the nature of the scene (Kruger *et al*., 2017). The pertinent question we need to ask in AVT, is whether the AVT products affect the audience's ability to immerse. Since immersion is very much related to enjoyment, it is important to know whether our AVT products allow the target audiences an equivalent level of immersion into the story world, and likewise, similar levels of enjoyment.

The two main constraints with post-hoc measures are their subjective nature and the fact that they cannot provide online measurements and rely on memory. For this reason, it is important to combine these measures with online and objective measures such as eye tracking (that can provide information on where sighted viewers attended) and EEG, in particular beta coherence as we will explain here.

4. Research Design

4.1. Introduction

The overarching aim of the project is to develop further understanding of how immersion can be measured objectively, and how this can be applied to an accessibility context including subtitling, captioning, and AD across different genres and platforms. In the context of this study, more specifically, we are interested in (1) determining if electroencephalography (EEG) can be used as a measure of immersion, and if (2) subtitles have an impact on immersion as measured in this

manner. As a first step, this paper describes the validation of the methodology (1) and the effects of subtitles (2) in order to advance to the application to AD (3). In order to achieve these aims, the study adopted an experimental design in which there were two conditions: a treatment condition in which participants were exposed to the subtitled version of the film (n = 20); and a control condition without subtitles (n = 21). Participants, described below, were randomly assigned to conditions.

4.2. Materials

The first 30-minutes of a feature-length movie were used. *Sherlock Holmes: A Game of Shadows* was used as it is a highly-successful mainstream film with a fictitious plot and characters. The 30-minute can be broken down into a series of discrete scenes as per Table 1.

Scene	Event	Duration (sec)	Description
1	Watson opening narrative	47.64	Exposition by Watson
2	Marketplace	113.96	Holmes in disguise meets up with Adler
3	Beating	122.4	Holmes is beaten up by Moriarty's goons
4	Auction	119.96	Holmes prevents bomb from exploding
5	Assassination of Adler	152.32	Moriarty poison's Adler after telling her he has no use for her
6	Holmes being stood up	22.92	Holmes waits for the now deceased Adler
7	Title screen	6.52	Freeze frame, title
8	Apartment	394.36	Watson enters Holmes's apartment, Holmes in disguise, they discuss the conspiracy
9	Car and Mycroft	182.8	Comic relief as Holmes in disguise banters with Watson on way to the club
10	First club scene until Holmes joins gypsy	139.12	Holmes looks for assassins during Watson's stag party
11	Fortune teller scene	201.16	Holmes meets fortune teller whose brother was corrupted by Moriarty
12	Fight scene	259.04	Holmes fights Cossacks

Table 1: Breakdown of scenes in film.

4.3. Sampling

Convenience sampling was used to recruit English L2 viewers from Macquarie University in accordance with the institution's ethics requirements for research involving human participants. Participants were contacted via a general e-mail to the study body. Participants were compensated for their time with course credit. This sampling method resulted in 41 participants with English L2 and Mandarin L1, where all participants had intermediate to high English L2 proficiency with IELTS scores of above 6.5 on all bands; had spent an average of 27 months in an English-speaking country; a mean age of 26 years with a range between 19 to 49.

4.4. Method

A combination of online and offline measures were used to align with the aims of the study. Participants were tested individually in a research laboratory with sound and light insulation, see Figure X. Each data collection took approximately 1 hour.

A well-established offline immersion questionnaire with a set of sub-items was used consisting of 23 items on 7-point Likert scales (see Appendix):

- 10 items on transportation (adapted from Green and Brock, 2013);
- 4 items on character identification (adapted from Tal-Or and Cohen, 2010);
- 8 items on presence (adapted from Kim and Biocca, 1997);
- 1 item on general enjoyment.

Reliability of the questionnaire was found to be above the acceptable level (= 0.898).

EEG was employed as an online measure of immersion using beta coherence, frequency range between 14-30Hz, between the prefrontal (PFC)and posterior parietal (PPC) cortex. In cognitive neuroscience, the prefrontal cortex is considered to be the location for the control of cortical or executive processing, while the posterior parietal cortex is considered the location of neural activity linked to the imagination, becoming particularly active when we imagine ourselves as someone else or at another time or place (cf. Shimamura, 2013:13-14). In particular, Shimamura states that "the posterior parietal cortex must be considered as a critical structure for psychocinematic investigations" (2013: 14). Coherence between the PFC and the PPC gains particular relevance in the study of immersion in a fictional world due to the role of the prefrontal cortex in modulating affective states across other regions. According to Reiser, Schulter, Weiss, Fink, Rominger, and Papousek (2012:144),

> there is evidence that the prefrontal cortex receives highly processed sensory information and in turn exerts feedback control on posterior association cortices, in order to further modulate representations of affectively relevant information.

Reiser *et al.* (2012) therefore investigate the individual differences in state-dependent decreases or increases of EEG coherence between the PFC and PPC to determine whether these differences indicate the modulation of emotions. In their study, they found that decreased beta coherence was linked to higher trait absorption and the propensity to ruminate when participants were asked to sympathize with others, whereas beta coherence increased when participants did not absorb traits or were unable to ruminate. Based on these findings, this paradigm will be used in this study to measure psychological immersion in the presence or absence of subtitles.

EEG data were collected using the EMOTIV Epoc+ headset. The headset has previously been validated for capturing EEG data of this nature (Badcock, Mousikou, Mahajan, de Lissa, Thie, and McArthur, 2013). We calculated spectral coherence on the beta band from left and right hemispheres and prefrontal and posterior regions, where an increased level of beta coherence is linked to less emotional involvement (cf. Reiser *et al.*, 2013).

Figure 1: Experiment setup

Features were extracted from the EEG data by obtaining raw signal data from the individual datasets. Artefacts including blinks and heartbeats were removed. Data were then filtered and transformed to obtain the beta frequency. The beta band spectral power distribution was then analysed to calculate beta coherence. This process is detailed in Figure 1.

More specifically, artefact rejection was performed to remove any noisy EEG recordings by rejecting trials with variance greater than 400 μV^2 within any of its channel's recordings. Each of the accepted trials was transformed into the

frequency domain using the Fast Fourier Transform (FFT). The cross-spectrum coherence was calculated from the FFT spectrum for each electrode pairing from each scene. Coherence from electrode pairing of P8-F8, P8-F4, P8-F3, P8-F7, P7-F8, P7-F4, P7-F3, P7-F7 was averaged to form the fronto-parietal coupling. Beta coherence was then calculated by averaging frequencies from 14-30Hz in segments of 10 x 0.5sec intervals (every 5 seconds).

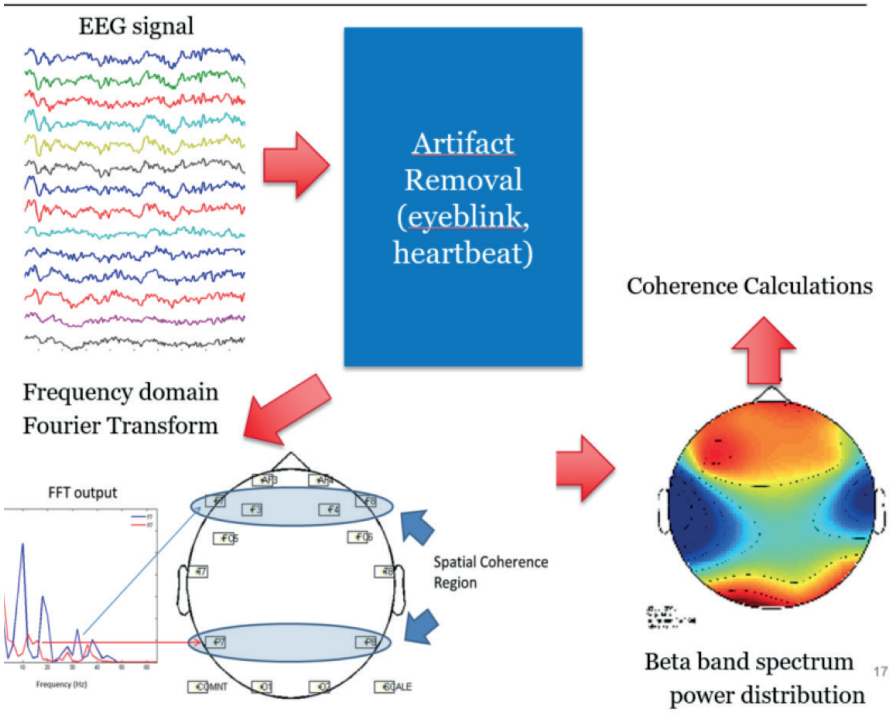

Figure 2: EEG data processing workflow

5. Results

5.1. Self-reports

Somewhat surprisingly, no statistically significant difference was found on any of the subsets of immersion. This was particularly surprising since a previous study, making use exclusively of post-hoc measures, found significantly higher transportation and character identification in the presence of subtitles after watching an episode of a medical drama series (see Kruger *et al.*, 2016; Kruger *et al.*, 2017). There are a number of possible explanations for the lack of significant differences in this study. In the first place, this experiment only used the first half

an hour of a film, not a full text as in the previous study, so the overall immersion may not have had sufficient time to diverge between conditions. In the second place, there is a limitation in using post-hoc questionnaires namely that they do not allow for the analysis of variation in immersion in the course of the film, and the scenes used in this experiment consisted of a range of different scene types as evident in Table 1.

5.2. EEG BETA COHERENCE

As the distribution data shows in Figure 3, the beta coherence varies across the scenes. As illustrated in the graph, for both conditions the beta coherence decreases from the opening narrative to the marketplace and beating scenes as well as the auction and the assassination scene, before increasing in the two short scenes where Holmes waits for Adler and the title screen. The coherence then decreases again for the remaining scenes. With the exception of the first two scenes, the coherence is lower for subtitled than unsubtitled, i.e. immersion could be said to be higher. This difference reaches statistical significance with the subtitled movie presentation eliciting lower beta coherence (between PFC and PPC) than the unsubtitled version. In other words, there was a significant difference between conditions ($F(2,1080) = 51.475$, $p < 0.001$) with the coherence for the unsubtitled condition being significantly higher than for the subtitled condition. This significance has a medium effect size with a Cohen's $d = 0.5$.

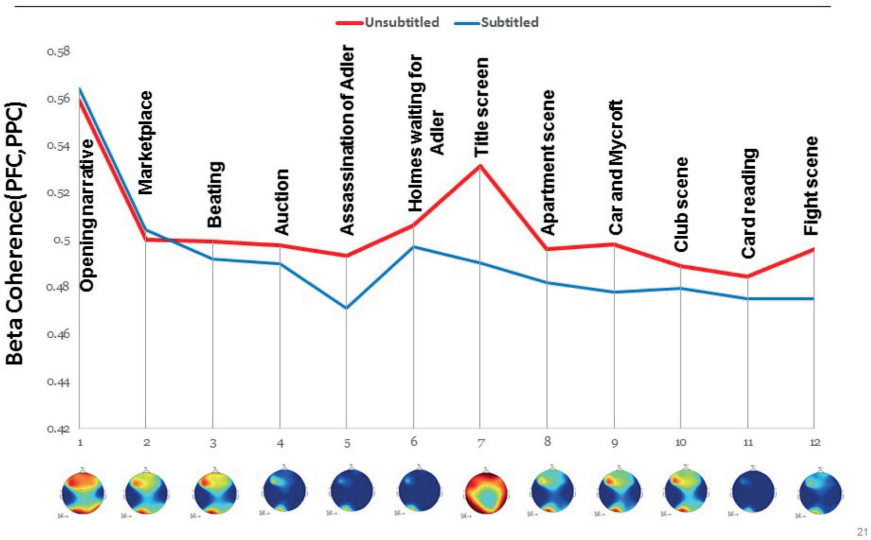

Figure 3: Beta coherence per scene

6. Discussion

Our results provide further empirical evidence of the lack of negative effects of subtitles on immersion, a finding that supports previous studies that employed solely offline measures (e.g., Kruger *et al*. 2016; 2017). This also adds to the benefits of subtitles reported on more generally (Gernsbacher, 2015). Our contribution in this study is the addition of an online, more objective, measure of immersion, which showed a further effect in terms of the positive impact found for this measure of immersion.

What is particularly interesting, is the fact that beta coherence between the PFC and the PPC seems to be sensitive to variations across different scene types. This is therefore a step in the direction of establishing a scientific methodology for the online investigation of cognitive processing of AVT products.

Measuring the cognitive processing of film, and also film together with subtitles or dubbing or AD is complicated by the polysemiotic nature of the text since elements such as text, moving images and sound have to be processed simultaneously. This makes it hard to determine the contribution of individual elements. In AD, the original soundtrack and dialogue have to be processed together with the AD, resulting in a complicated mixture of sounds from the story world, and the voice of the audio describer providing information on the visual scene. Before we can begin to adjust our AD practices, we need to understand the contribution of different sources of information in different combinations to the processing of an audiovisual text. And we need to get this understanding not only in relation to blind or partially sighted audiences, but also for all kinds of audiences.

The next step is to use the same methodology to investigate the processing of different versions of AD on immersion. In the context of AD this will have the potential of comparing the impact of audio description in different scenes on blind or partially sighted audiences to that of sighted audiences.

In conclusion it can be said that although self-reported measures such as transportation scales are rich in subjective meaning, they are arguably limited and biased. EEG, particularly beta coherence, shows promise to be used as an objective tracking measure of audio-visual text on immersion that could be used to evaluate different styles of AD across different genres and populations.

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Items from immersion questionnaire.

Transportation (Adapted from Green and Brock, 2013):

1. While I was watching the drama, activity going on in the room around me was on my mind.
2. I could picture myself in the scene of the events depicted in the drama.
3. I was mentally involved in the drama while I was watching it.
4. After I watched the drama I found it easy to put it out of my mind.
5. While watching the drama, I wanted to know how it ended.
6. The drama affected me emotionally.
7. I found myself thinking of ways the drama could have turned out.
8. I found my mind wandering while I was watching the drama.
9. The events in the drama are relevant to my everyday life.
10. The events in the narrative have changed my life.

Character identification (Adapted from Tal-Or and Cohen, 2010):

1. I think I understand the character of XXX.
2. I understood the events in the drama the way XXX understood them.
3. While I was watching the drama, I felt like XXX felt.
4. During viewing, I could really "get inside" XXX's head.

Presence (Adapted from Kim & Biocca, 1997):

1. When the drama ended, I felt like I came back to the "real world" after a journey.
2. The drama came to me and created a new world for me, and the world suddenly disappeared when the drama ended.
3. While watching, I felt I was in the world the drama created.
4. While watching the drama, I forgot that I was in the middle of an experiment.
5. While watching, my body was in the room, but my mind was inside the world created by the drama.
6. While watching, the story world in the drama was more real or present for me than the "real world."
7. The story world seemed to me only "something I saw" rather than "somewhere I visited."
8. While watching, my mind was in the room where I watched the drama, not in the world created by the drama.

Enjoyment:

1. Did you enjoy the film?