# AUDIOVISUAL DISTURBANCES IN ONLINE EDUCATION – AN OVERVIEW OF CURRENT RESEARCH AND A SUGGESTED FUTURE RESEARCH INITIATIVE

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## Abstract

Disturbances is a recurring phenomenon in online education not yet resolved. A particular sub-set of these are audiovisual disturbances, stemming from online education always being mediated by some sort of digital technology. Here, a research overview of current research on audiovisual disturbances in online higher education was made for research articles and conference papers in the databases ERIC, Scopus and Google Scholar, identifying seven themes: *communication*, *audiovisual perception* and *quality*, *fluidness*, *fatigue*, *cognitive load*, *measurements* of these categories, and, as a sub-set, *eye tracking*.

A key factor for student success in online learning is the user-experience of seamlessness in teaching and e-tutorial situations. Such seamlessness allows for immersion, which supports a better personal situatedness, than during campus teaching. Further, both gamification and interactivity support immersion and the sense of "flow" (Csikszentmihalyi, 1990) in the learning situation. However, the flow of information, at least in part, need to be adjustable for the student.

Any kind of malfunction of a digital tool or connection causes disturbances in communication, which exists in numerous variants. Video is considered to provide better communication by students than only sound or text, even though quality of sound is crucial to teaching and learning success. Quality of content is more important though than the technical standard of video. Short, high-quality videos seem to render better student engagement at lessons. Yet, students need to have technical readiness to sustain online education. Online education also comes with the risk for several forms of fatigue: fatiguing course material, and solitude fatigue felt by students, compassion fatigue on behalf of teachers, and "Zoom fatigue" for all. Particular fatigue measurements have been developed.

Another effect of the online education situation is the vulnerability to cognitive load. Negative cognitive load arises as an effect from attention split, in turn caused by disturbing details, cueing and signals, and differences in information modalities. Particularly distracting is complex information presented in VR environments. Several studies consider cognitive load during the use of video in the teaching/learning situations: for instance, the effects of video length, teacher presence, or external cognitive load. A few cognitive load measurements include objective data such as mouse clicks or time consumption, whereas most cognitive load measurements rely on subjective reporting of experience via questionnaires or scale indications. Not all cognitive load is negative though, so there is a differentiation between external, internal (both negative) and germane (positive) cognitive load. However, there are some indications that course content might be possible to improve by better design, taking cognitive load into regard.

Eye-tracking provides a particular non-intrusive means for objective attention measure. It is used to study attention to web-page layout, during video usage, or text reading as well as course assignment work – all online. Yet, I found no studies that use eye-tracking to examine cognitive load, although it is feasible to do so.

As for a future research initiative, I suggest exploring cognitive load in online education by means of eye-tracking, to capture which disturbances to avoid, to reduce extraneous cognitive load for students.

Keywords: immersion, audiovisual disturbances, cognitive load, measurement, eye-tracking.

## 1 INTRODUCTION

In the optimal online learning situation, the complexity of information is what it must be for the assigned learning task or condition, but without unnecessary complications. Likewise, the external configuration of the information and its mode of communication is as comprehensible and unconstrained as possible, which leads to a situation where full focus is dedicated to learning, and a cognitive flow with maximum learning can occur [1]. When this state of flow occurs, and is maintained, the phenomenon of immersion can happen, which is an ideal state when the learners mind expels the outer world, and the learning experience is all there is [2]. The learning experience becomes a “world” of its own.

In cognitive science terms, the study of the mind at work – working memory – is operationalized via the concept of cognitive load. When the mind works on the acquisition of knowledge, the cognitive load is germane, a dedicated and necessary workload [3]. However, cognitive load is also provoked by the configuration of information (extraneous cognitive load), as well as the complexity of the information (intrinsic cognitive load) which is workload that in instructional design must be optimized for the learning task for best knowledge acquisition [4]. Any internal or external element that adds extra cognitive load reduces the working memory resources possible for the mind to allocate to learning. In this paper, I will highlight external, audiovisual factors that add extraneous cognitive load, since knowing these factors makes them possible to mend.

However, much like when a movie is badly made and draws attention to its fabrication [cf.5], the learning immersion might easily be broken down by external elements catching the learner’s attention, possibly provoking awareness, or even entering consciousness. In the online situation, we all succumb to the usage of digital tools, which are either visual/haptic or audiovisual/haptic, and any sound or visual element that does not contribute to what is taking place during the learning immersion phenomenon might instead provoke the opposite – the break-down of immersion by competing for attention through audio or visual perception. Whenever these sound or visual elements succeed in breaking down immersion, learning flow halts, and extraneous cognitive load appears, and learning lessens or ceases. Therefore, understanding when, where, and how audiovisual disturbances occur in online higher education, as well as their effect, will contribute to knowledge in the field of online education by exposing factors not yet fully attended to, for further development.

Disturbances – even on a micro-level – cause negative cognitive load because they compete for attention, and the mind must work extra hard to either suppress them, recognize and deselect them, or shift attention back and forth between the disturbances and what the mind was supposed to focus on [6], [7], [8]. Audiovisual disturbances include any sound or visual phenomenon that competes for an individual’s attention, whether or not that individual becomes aware of the phenomenon, or consciously attends to it.

Thus, the purpose of the current research overview is to provide a basis for further studies on audiovisual disturbances in online higher education. The aim is to provide an exposure of where existing knowledge gaps are found and how they appear, in order to be addressed by future research.

## 2 METHOD

For an overview of audiovisual distortion in current research on online higher education a literature search was carried out in the databases ERIC, Scopus and Google Scholar, limited to results in English, covering publications back to 2018. (Older research was considered being of less interest due to online education’s dependency on digital technology and its rate of development.) The search combined 37 words in a Boolean combination: (higher education OR university education) AND (distance education OR distance learning OR distributed learning OR e-learning OR flexible learning OR internet based learning OR internet education OR internet learning OR net based education OR net based learning OR online learning OR open learning OR technology enhanced learning OR tele-learning OR web based learning) AND ([audio AND video] OR audiovisual OR attention OR cognitive load OR disfluency OR disruption OR distraction OR disturbance OR eye movements OR fatigue OR flow OR interfere* OR interrupt* OR [quality AND perception] OR [quality AND communication] OR [sound AND video] OR seamless* OR transients) NOT (mooc* OR massive OR covid*) in titles, keywords and abstracts. Massive online courses (MOOCs) were disregarded since their forms and student numbers differ significantly from regular online education, and subsequently their pedagogy. For the same reason, conclusions from the emergency state taking the pandemic were also excluded.

After removing duplicates 884 research articles and conference papers were considered proper hits, whereof 258 were found relevant when reading their abstracts. Seven themes were identified by content analysis, as regarding audiovisual aspects of disturbances, and how to measure such aspects, according to the main perspective of the respective text: audiovisual perception and quality (20), cognitive load (86), communication issues (21), fatigue (13), fluidness (12), measurements of these categories (86), and, as a sub-set of measurement, eye tracking (20). The particular reason for a devoted interest in eye tracking is the possibility of such a method for objective, non-intrusive measurement of (disturbances to) visual attention, as well as to cognitive load, which is a big advantage of this method.

# 3 RESULTS

The literature that concerns audiovisual distortions does not generally focus on these aspects as their main result, but more often mention them as part of their outcomes. A summary of the findings is presented below, where audiovisual aspects are highlighted, and other aspects are declined.

## 3.1 Audiovisual aspects of disturbances

### *3.1.1 Communication*

Since communication in online higher education is entirely dependent on digital tools, the proper functioning of such technologies, end-to-end, is a core prerequisite for teachers as well as students [9], [10], [12]. When malfunctioning occurs at either end, or concerning the connection between them, there are disturbances in the communication, usually in audiovisual form. These audiovisual disturbances appear as lagging or frozen images, or sound gaps, or sound-image delay, and several other forms, with a consequence of bad communication flow, deficient information transfer, interruption, fatigue and more [10].

What seems important to students are: (1) the interaction with teachers [11], [12] and (2) information quality [13], both affected by audiovisual disturbances. However, there are no conclusive results regarding whether these student appreciations are aspects that affect learning outcomes. What is critical for learning success, though, is that the students have the technical readiness to sustain online education [10], [14].

### *3.1.2 Perception and quality*

Audiovisual quality has both a technical aspect and an experiential aspect, a duality considered in the literature. Likewise, audiovisual perception may refer to sensory aspects of meeting audiovisual media, as well as to processing of audiovisual information, which is recognized in the following. Previous research on online higher education is conclusive that well-functioning information and communication technologies (ICT) – particularly the quality of sound – is crucial for understanding spoken language, and therefore affects communication, interaction, and learning success, which is confirmed in the current overview [10], [15]. Similarly, it is claimed that the online forms of teaching must be designed, so that learning materials, activities, and ICT tools used match each other, in order to fit with intrinsic properties of the tool, for example audiovisual limitations [16]. Low degree of interactivity as well as low video quality is not appreciated by students in terms of learning experience though [17]. However, video as a complement to existing teaching seems to have a positive impact on learning [18].

There are findings that students prefer video as a better form of communication than only text or sound [19]. Yet, it is the quality of the course content and the teaching that matter the most, more than the technical-aesthetical standard of the video communication [20]. In terms of student engagement, short, high-quality videos seem to be best at rendering such engagement at lessons [21].

### *3.1.3 Fluidness*

The experience of engagement and involvement builds on a sense of immediacy in interaction in the online situation, which in turn presupposes an inherent audiovisual fluidness of the ICT tools used. When such fluidness prevails, the student's user experience of seamlessness – technical tools and interfaces regarded – is supported, which, in turn is very favourable for learning when interactivity brings the sense of "flow" both in teaching and e-tutorial situations [2]. Some report that such seamlessness leads to immersion, and thereby a better personal situatedness than is the case in traditional classroom teaching [22].

Other results point out that the use of newer technologies, for instance virtual reality, in combination with gamification and other forms of interactivity are particularly good at supporting immersion, and thereby the sense of flow, during teaching and learning online [23], [24].

There are other aspects of flow that need attention though. It is beneficial for the student to be able to regulate the flow of information in the learning situation, not to be stressed [25], and the supervisor must attend to the flow of discussions amongst online students, to encourage fluid mutual learning [26].

### *3.1.4 Fatigue*

The opposite of fluidness might be said to be the fatigue reported to occur when the seamless flow of the learning situation is not maintained, or when the teaching material is not well adapted for the particular ICT tool or learning situation [27]. "Zoom fatigue" is a reported online education phenomenon as well, which hits both students and teachers [28]. Another form of fatigue comes from the solitude felt by online students [29]. Teachers also experience a kind of online compassion fatigue, referring to a fading capacity for empathy with struggling students [30]. Video gaming has shown to reduce online learning fatigue though, by the emotional intensity evoked by the engagement in the game [31].

Measurements aimed at estimating online fatigue have been developed, see for instance [27], [32].

### *3.1.5 Cognitive load*

As a simplification: during learning – online, or otherwise – the mind is occupied by our working memory trying to process information into knowledge which entails active cognition. Therefore, studies of what causes cognitive load, and how during online learning is of particular interest. Some learning implies a high cognitive load, whereas other learning implies low, yet providing a high degree of learning [33]. Also, high social interaction correlates with high cognitive load, and contrary, low social interaction with low cognitive load [34], [35], which in online learning implies social interaction via audiovisual means. Student vulnerability to cognitive load during online education situations is studied per se [36], but also teachers are affected [37].

Extraneous cognitive load often arises as an effect from the amount and complexity of information [38], or from attention split in the learning situation [39], which is in turn caused by disturbing details [40]. Also, different kinds of cueing and signals [33], [40, [41], as well as different information modalities used in the online learning environment during self-organized studies [42] can cause extraneous cognitive load. All these external factors include audiovisual aspects due to the dependence on ICT tools.

Cognitive load during use of video in online teaching/learning situations has drawn distinct research attention: for example, video duration time matters to cognitive load [43], teacher presence or not has been studied [44], video reduces extraneous cognitive load which then supports learning [45], but whereas virtual reality (VR) causes higher cognitive load than video while also providing better learning [46]. Complexity and amount of information presented in VR environments is on the one hand found to cause extraneous cognitive load [33], [47], while on the other hand the immersion taking place when using such more recent technologies (AR/VR) reduces cognitive load [48].

Most studies are carried out by means of different (subjective) self-assessment methods [40] where participants report their experiences, such as self-reported questionnaires [49], and only few studies use objective measurements of psychological parameters, actions, or reaction time [49]. Cognitive load studies also primarily focus on multimedia design, materials, presentation formats, and individuals' prerequisites [40]. A particular take on cognitive load in online education is to let cognitive load theory inform the design of instructions and materials in online courses [50].

## 3.2 Measurements of audiovisual aspects of disturbances

There are several measurements developed for phenomena occurring during online studies, aimed at capturing effects on the online education situation, stemming from such various disciplines as pedagogy, psychology, information and communication technology, language, mathematics, and science. Measurements of perception, quality, engagement, fatigue, or cognitive load are of particular interest in this paper, which will be reported below according to their character of being either subjective or objective.

Fluidness, seamlessness and immersion are categories for which there are no separate measurement reported on in the literature, but these categories occur in discussions of engagement, which is measured and accounted for. There are measurements that use subjective reporting of experience via questionnaire surveys, including free text answers, given options and scale indications, and interviews, as well as measurements based on objective data from tests, observations, user logs, and psychophysical instruments capturing data from the human body. There are both subjective and objective measurements for all categories, except for quality, for which I found only subjective measurements.

### *3.2.1 Subjective measurements*

The subjective measurements employed for capturing data regarding issues of perception, quality, engagement, fatigue, cognitive load, or other aspects of online education are usually surveys with students and/or teachers. These surveys are commonly questionnaires with pre-defined options, some using Likert (or other) scales for rating statements, but some also include free-text answers. Many surveys are unspecified as to associated with a specific methodology, e.g. [10], [25], [51], whereas some use a multifactor analysis with a structural equation modelling (SEM) technique, e.g. [13], [14], [52].

In Table 1 subjective measurements are presented that include survey or other data in specified methods with specific purposes and perspectives. Some of those are built on the same basic method, for instance the SERVQUAL model, but are altered – usually added to – in one way or another. In a few studies, e.g. [53], [54] surveys are combined with more objective data from quizzes and tests.

*Table 1. Subjective measurements of perception, quality, engagement, fatigue and cognitive load.*

| ***Perception*** | ***Quality*** | ***Engagement*** | ***Fatigue*** | ***Cognitive load*** |
|---|---|---|---|---|
| Quality Perception of Online Discussion Forums (QPODF) scale [55] | The ELQ model [60] | Online Homework Distraction Scale (OHDS) [64] | Student Mental Fatigue Survey (SMFS) [32] | E-Text Frustration scale (ETFS) [68] |
| E-Learning Educational Atmosphere Measure (EEAM) [56] | Behavioral Anchored Rating Scales (BARS) [61] | Tutorial understanding and Network skills [65] | Online Course Overload Indicator (OCOI) [32] survey | Tutorial understanding and Network skills [35] |
| Extended Technology Acceptance Model (TAM2) [57, 58] | Technological Achievement Index (TAI) [62] | User Engagement Scale [66] | Motivated Strategies for Learning Questionnaire [27] | Cognitive Load Scale: extraneous, intrinsic, germane [36, 66] |
| Accessible Technology Initiative (ATI) compliance measure [59] | Extended Technology Acceptance Model (TAM2) [57, 58] | | Scale of Attitudes towards New Post-Pandemic Scenarios (SANPS) [67] | Cognitive Load Index [66] |
| Learning Management System (LMS) Acceptance Model [9] | | | | High-fidelity (HF) and Low-fidelity (LF) virtual learning resources (VLRs) [53] |
| Attention, Relevance, Confidence, Satisfaction, and Volition (ARCS-V) model [54] | Visible Learning (VL) [63] | | E-Text Frustration scale (ETFS). [68] | |

### *3.2.2 Objective measurements*

There is a variety of objective measurements employed for capturing data concerning online education issues of perception, engagement, fatigue, or cognitive load, on behalf of students and teachers. No objective measurement for quality was found. Some objective measurements are framed as specific pedagogical tests in different subject areas where learning for online instructed student groups is compared to on-campus instructed, case-studies with similar randomized groups and the same instructors [69], [70]. These studies usually combine several measurements, such as pre-test and post-test that include learning outcomes and many other aspects of the teaching/learning situation.

*Table 2. Objective measurements of perception, engagement, fatigue and cognitive load.*

| ***Perception*** | ***Engagement*** | ***Fatigue*** | ***Cognitive load*** |
|---|---|---|---|
| Electro-Encephalo-Graph (EEG) Analysis for Learning Behavior [73], [74], [77], [78], [79] (attention); [75], [76] (perception) | EEG-Analysis for Learning Behavior [73], [74] | EEG-Analysis for Learning Behavior [73], [74] | Mouse-click [89] |
| | Reactions to facial expressions [82], [83] | Reactions to facial expressions [82], [83], [87], [88] | Time spent [89], [90] |
| Headset sensor (reading neural oscillations) [80] | Mouse movements [82] | | EEG-Analysis for Learning Behavior [75], [76] |
| | Time spent on activities [84] | | |
| Mechanics-Dynamics-Aesthetics (MDA) framework [81] | MDA framework [81] | | Galvanic Skin Response (GSR), and Skin Temperature (ST) [91] |
| | Activity score + survey [53] | | |
| | Frequency of contributions (to collaboration) [85] | | |
| | Impact (in coll.) [85] | | |
| | Video access log distribution [86] | | |

Then there are specific measurements with the purpose of capturing human psychophysical conditions during teaching/learning activities. Some of those are cognitive neuroscience methods; for a review, see [71], whereas others are distinctly aimed at measuring students' attention during online learning activities; see [72] for a review. Other measures include activities such as mouse usage, user logs, time usage, activity metrics, and reaction to facial expressions, see Table 2.

Perception is studied via electro-encephalo-graph analysis (EEG), headset sensors reading neural oscillations, and the mechanics-dynamics-aesthetics (MDA) framework for gamification [81], and particular interest is paid to attention. Engagement is also measured by means of EEG, but also by a range of other measures: reaction to facial expressions, mouse movement, time spent on activities, video access log distribution, activity score, the MDA framework, frequency of contributions, impact on collaboration. EEG and reaction to facial expressions are also used to measure fatigue, whereas cognitive load is measured by means of EEG, galvanic skin response (GSR), skin temperature (ST), as well as mouse-clicks, and time spent, both during activities.

#### *3.2.2.1 Eye tracking*

Objective measurements of cognitive load or other phenomena that students experience during their studies entail tests of different kinds where laboratory instruments of some sort are used. Each test method and type of instrument brings an alteration to the normal learning situation, and thus affects it. Eye-tracking is an established method for objective attention measure which, contrary to EEG, GSR, ST, and similar methods, does not interfere with the participant's body in any other way than the participant using a computer interface (screen, keyboard, and mouse), which are familiar standard tools for most students today, and in that sense non-intrusive. Hence, eye-tracking can capture disturbances to attention via registering odd and unmotivated eye movements, caused by digital audiovisual traces or other disturbances to the online teaching situation that affect the seamless flow and immersion during the online learning situation, with less impact on the situation than other objective methods. Also, eye-tracking can capture pupil dilation which indicates cognitive load.

The studies of online education that have applied eye tracking have used it to study attention to web-page layouts of different ICT tools and functions from various situations of learning processes [92], impact of multimedia design on student motivation [93], student attention during video usage in online lessons [94], as well as processing during course assignment work [95]. Results show that when attention is high, eye movements are synchronous across participants, and correlate with better course results [96].

During text reading online eye-tracking has been used to discriminate between superficial or in-depth learning related to interest, as well as patterns of reading and time [97]. Further, the effects and efficacy of direct or indirect feedback have been tested by means of eye-tracking [98]. A particularly interesting study was made on feedback via eye-tracking (students watching their own eye movements after using a digital dictionary, and then reflecting on their study behavior) as a learning method [99].

Studies have been made that compare the emotional intensity (engagement) between online students and onsite students, in which the factors interest, attention and stress were combined, and eye tracking was combined with GSR and EEG [74].

Yet, I found no research applying eye-tracking to examine pupil dilation for cognitive load during teaching and learning, although the method is appropriate for that purpose, and could follow cognition closely.

## 4 CONCLUSIONS AND FURTHER RESEARCH

There is a variety of measures – subjective as well as objective – for aspects of online education that in different ways include audio-visuality, and where audiovisual disturbances make an impact. Subjective measures can indicate under which circumstances such audiovisual disturbance impact occurs, but in order to do so, a systematic meta-analysis would be needed across a wide range of completed studies to discriminate between their measured components, as well as their results. Objective measures could then be applied to study specific situations where particular audiovisual disturbance impact is expected. Immediate reactions, conscious and unconscious, to disturbances can be measured via eye tracking, and subsequent cognitive load will also be captured then. The kind of cognitive load, extraneous, intrinsic, or germane, can then be traced per individual by subjective methods or cognitive tests.

Hence, I suggest as a future research initiative to explore reactions to audiovisual disturbances and subsequent cognitive load in online education by means of eye tracking to grasp when and how audiovisual disturbances happen, and combine eye tracking with a survey to understand when extraneous, intrinsic, or germane cognitive load is taking place. That will make it possible to distinguish between what is unconsciously reacted, or attended to, and what causes conscious awareness, which in turn may be used when designing online learning situations from a cognitive load theory perspective.


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