In Focus

# Cinematographers' Perceptual Professionalization from Novices to Experts: Observations from an Eye-tracking Case Study

sciendo

**ELEN LOTMAN,** Tallinn University, Estonia; e-mail: elen.lotman@tlu.ee
**MATI MÕTTUS,** Tallinn University, Estonia; e-mail: matim@tlu.ee
**PIA TIKKA,** Tallinn University, Estonia; e-mmail: pia.tikka@tlu.ee

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## ABSTRACT

**Cinematographers represent a group of experts whose professional skills depend to a great extent on their visual perceptual abilities. By the term *perceptual professionalization,* we emphasize the embodied dynamics of perceptual learning processes that shape the ways in which cinematographers make creative decisions during their daily practices. Novice cinematographers are initiated in film schools and during assisting jobs to a range of technical skills required for working as heads of the camera department in film productions. However, honing one's perceptual skills as a professional cinematographer is nothing less than a lifelong process. While scientific studies show evidence for behavioral and physiological differences between experts and novices in many different fields, so far no such studies exist between professional cinematographers and novices. As a starting point for studying how cinematographers' perceptual learning evolves from the level of novice to that of experienced professional, we assumed that the different expertise levels of cinematographers can be observed in the way they view moving images. We then conducted an eye-tracking case study where we identified differences in the gaze patterns between film professionals with different levels of expertise in cinematography during viewing a film trailer. As the experiential heuristics of creative decision-making of professional cinematographers largely rely on the practical skills accumulated in film work, in order to gain access to such knowledge, we also report how involving a practicing cinematographer both in designing the study and in analyzing the results provided us new insights to the topic under scrutiny. Based on our findings, a new study protocol is proposed.**


**KEYWORDS:** cinematography, perceptual learning, embodied mind, neurocinematics, eye-tracking

## INTRODUCTION

Cinematographers can be seen as artists, technicians, team leaders, or audiovisual storytellers, but above all they can be characterized as professional see'ers (Lotman 2017). This skill of seeing develops throughout one's career, from film school to assisting jobs in camera departments to higher positions that carry full responsibilities of the cinematographic decisions, such as Director of Photography (DoP), which as a position in film production is considered Head of Department (HOD) level. When skills required from a cinematographer are listed, they typically relate to the practical and technical maneuvers at the set, such as managing the camera equipment and the crew, making decisions for camera lenses, framing of images, and so on. These skills also tend to receive most attention in the film schools' training programs, while less attention is paid to the cognitive learning processes of how professional perception of cinematographic images develops over time.

Likewise in any domain of expertise, *perceptual learning* (Gibson 1963; Goldstone 1998; Fahle, Poggio 2002; Prettyman 2019) is assumed to form the foundation of a cinematographer's professional development. When talking of cinematographers' perceptual learning, we refer to the embodied cognitive processes that build on the lifelong experience of seeing and creating cinematic images from the specific cinematographic point of view. Such perceptual learning not only precedes professionalization but also ensures lifelong professional development of practicing cinematographers, a process we refer to as *perceptual professionalization*. Perceptual professionalization of cinematographers is regarded as involving continuous improvement of skills, evolving in synchrony with filmmakers' experience-based cognitive processes (de Borst et al. 2016) and emerging through cinematographers' personal experiential heuristics, a type of tacit knowledge that has emerged and been adopted and adapted along iterative work in film productions (Lotman 2021).

No scientific studies – to the best of our knowledge – focus on cinematographers' perceptual professionalization. To start filling this vacuum, in what follows we will outline possible directions for studying cinematographers' perceptual learning and how it evolves from the level of a novice to that of an experienced professional. An extensive body of previous studies on multisensory perceptual learning in general (e.g. Bilalić 2017; Dosher, Lu 2020) as well as on visual perceptual learning in particular (see Sagi 2011; Lu, Dosher, 2022, for reviews) will provide us with fruitful insights for grounding such an endeavor. While a range of advanced quantitative methods are available in psychophysiology, neuroimaging, and computational data analysis, our main aim here is to lay cinematography-specific theoretical and practical groundings for conducting such studies in the future. How could a thorough scrutiny of perceptual professionalization be conducted so as to take into account the lifelong development of skills via professional practice of seeing and living by cinematographic images? Perhaps first comparing the ways of seeing of experienced cinematographers with those of novice cinematographers, to learn if and how ways of seeing differ between cinematographers and other filmmakers, could provide insights for proceeding toward longitudinal studies of professional development.

## PROFESSIONAL EXPERT PERCEPTION DIFFERS FROM NOVICE PERCEPTION

Several studies show initial evidence for differences between trained expert perception and untrained laymen perception both in brain connectivity and in observed viewing patterns. Especially art experts and non-experts have been extensively studied by tracking their gaze movements, with most of the findings revealing that while art experts typically scan the global composition of the artwork, laymen tend to focus on the figures or objects in the paintings (Nodine et al. 1993; Vogt, Magnussen 2007; Kapoula et al. 2009; Pihko et al. 2011;

Sharvashidze, Schütz 2020). Eye-tracking studies have reported better perceptual abilities of portrait artists in focusing systematically on details, when compared to novices (Miall, Tchalenko 2001; Hsiao et al. 2021).

It is expected that perceiving a still image or a dynamically moving image in narrative context has different effects on the tracked gaze. Any movement in the dynamical scenes tends to attract the synchronized attention of participants while static images typically show temporally dispersed gaze behavior (Smith, Henderson 2008; Smith, Mital 2013). This tendency of intersubject synchronization when people watch the same films has been repeatedly confirmed at the neural level in several neuroimaging experiments (Hasson et al. 2004, 2008; see Jääskeläinen et al. 2021 for a review). When compared with moving images, "eye movements on static images are initially driven by stimulus onset effects and later, more so than on continuous videos, by subject-specific idiosyncrasies" (Dorr et al. 2010: 1). The more the image follows the editing conventions of the genre films, the more the viewers are subject to the so-called tyranny of film, i.e., all of the viewers' attention is directed in synchrony to, let's say, aggressive faces, nude bodies, speeding objects, thus overriding the individual differences of the viewers (Loschky et al. 2015). However, Dwyer and Perkins (2018) showed in their eye-tracking studies that attentional synchrony of viewers may also take place in so-called slow cinema or art house films. In this case, the driver of the attentional synchrony may not be the motion on the screen but perhaps the captivating narrative that enhances the synchronized mental imagery (Hutson et al. 2022). The question for us in terms of cinematographically oriented perception of moving images is, to what extent does the gaze behavior of the test participants depend on the level of their perceptual professionalism? So far, only a handful of studies have looked at this specific question.

Andreu-Sánchez and colleagues conducted studies where they compared non-professional eyeblink rates with those of media professionals, such as producers, assistant producers, cameramen, image controllers, documentalists, graphic designers, post-production editors, sports commentators, and video editors. Their study revealed that media professionals' eyeblink rates decreased substantially compared to non-professionals' when watching edited audiovisual material (Andreu-Sánchez et al. 2017b) but interestingly also when viewing real-world events (Andreu-Sánchez et al. 2017a). In a follow-up study the researchers recorded electroencephalographic (EEG) signals from media professionals and non-professionals while they were watching audiovisual material; the results of the EEG studies suggested that the effective connectivity originating from the brain areas corresponding with the visual cortex, the somatomotor area, and the frontal area was stronger and seemingly more organized in media professionals than in non-professionals (Andreu-Sánchez et al. 2021). Furthermore, differences were observed in the EEG beta-band activity in the left primary motor cortex during viewing of motor actions in videos between media professionals and non-professionals (Andreu-Sánchez et al. 2023).

In a functional neuroimaging study on the expertise-driven brain plasticity of film professionals, de Borst and colleagues (2016) decoded from the whole brain data of cinematographers and sound designers whether they had been perceiving or imagining sounds or images of particular film clips. The data analysis revealed differences in the auditory or visual expertise-related brain areas, respective to the specification of professional expertise. Interestingly, the multivariate pattern analysis of the whole brain data also showed that cinematographers unconsciously differentiated fiction film clips from documentary film clips, even though this was not instructed and the use of these different film styles was not deliberately pointed out for the participants (de Borst et al. 2016).

The professional-level performance and related strategies (see Brams et al.

2019 for review) draw from a specific set of perceptual-cognitive skills building on behavioral, neural, functional, and structural dynamics of lifetime perceptual learning processes. The above findings on inhibited eyeblinks and specialized brain dynamics suggest abilities of professional cinematographers to patch together previous and new dynamically unfolding information from cinematic scenes in a manner different not only from non-professional viewers but also from other types of film experts. While these findings – the tip of the iceberg, if we may – do not come as a surprise to filmmakers, they do confirm that it is possible to identify functional behavioral and psycho-physiological patterns of embodied specializations in film professionals. Yet, such scientific findings may fail to detect the intricacies of the perceptual learning that are available to practicing professionals themselves. The solution we propose is to integrate professional expertise to the research process from the start. This would not only help us to focus on the research questions that present the core of the practice; it could further feed back to the early stage learning processes in the form of special types of teaching practices in film schools. Yet, as longitudinal behavioral and neuroscientific studies observing development of perceptual skills during development of cinematographic expertise during years of practice are non-existent, they need to be started almost from scratch. In the next section, we discuss a selection of studies that we categorize under the paradigm of *neurocinematics* (coined by Hasson et al. 2008). They apply methods from functional neuroimaging, psychometric measures, and eye-tracking studies mainly conducted with naive non-professional participants viewing films. We trust that their findings provide us with insights to the professional cinematographer's behavioral and physiological dynamics, when viewing cinematic material.

## NEUROCINEMATIC OBSERVATIONS ON FILM VIEWING AND PERCEPTUAL LEARNING

Cinematic images are composed of a multitude of dynamical variables, including movement, rhythm, lighting, color, sound, spatial staging, performing actors, and storyline, to name but a few. Most of these are understudied, if considered from a cinematographer's point of view, as is, for instance, cinematic lighting that is listed as one of the most important working tools by practicing cinematographers (Huttunen 2022; Voodla et al. 2020; Nevill 2018). The embodied multisensory integration of perceptual inference, decision-making, learning, binding, and attention in the brain (see Scheliga et al. 2022; Noppeney 2021 for reviews) enables the cinematographers to update predictive perceptual processes during performance. According to cinematographer Elen Lotman, the more professional expertise filmmakers have, the more they may rely on perceptual baseline heuristics, i.e., "creating images that are optimized for human perception" (Lotman 2021: 89) by controlling the natural eye catchers (light and color contrast changing, objects moving, etc.) that might diverge human attention from the main objects and also hide unnecessary objects. Our question is, how are these dynamical elements perceived by cinematographers in film viewing and during film production, and how can we expose them to enhance perceptual learning in the long run?

Practicing cinematographers describe their camera work and related decisions as follows: "when producing specific movements, cinematographers may be viewed as *extending* their perceptual bodily senses via the camera onto the screen, and in this sense, these movements may be further seen to become *embodied* in the viewer's experience" (Yilmaz et al. 2023). The neuroscientific observations of naive viewers' embodied responses to film content have been discussed (Tikka 2008; Gallese, Guerra 2012, 2019) and supported by a body of neuroscientific studies that emphasize filmmakers' role in enabling those responses (Hasson et al. 2004, 2008; Heimann et al. 2014, 2017, 2019; Kauttonen et al. 2015, 2018; Tikka et al. 2018; Voodla et al. 2020). We assume that, similarly as with viewers', the cinematographer's embodied action-perception system activates when seeing movements that can be observed by neuroscientific means. In addition, these embodied experiences could be assumed to show increased activations in the neuroscientific observations compared to the naive viewers, as the latter do not have embodied expertise in shooting such images.

Heimann and colleagues addressed the question of embodiment of camera movements with non-professional viewers. Analysis of their EEG signals revealed that steady camera movements produced most clearly mu rhythm activations in the participants' sensorimotor cortex as they simulated in a most natural manner the act of "walking" toward a staged actor (Heimann et al. 2014) but also approaching an empty space (Heimann et al. 2019). The frequency band components of mu rhythms are related to the key area in the human brain that is sensitive to the embodied simulation, or "neural mirroring," of perceived movements; mu rhythm decreases during sensorimotor activation (Gallese 2005; Hari, Nishitani 2004; Hari 2006; see Fox et al. 2016 for meta-analysis). As such, mu rhythm could provide us with a prominent key for future studies on cinematographers' perceptual learning and related decision-making during the acts both of viewing and of shooting a scene. Interestingly, Brunsdon and colleagues (2019) showed in a promising study that mu rhythm seems to become stronger in old age; however, how such a finding could be related to the action-perception expertise of cinematographers with more years of practice remains unclear.

Film productions tend to unfold during many months, even years, leaving a great part of the responsibility for the continuity and coherence of the final images on the shoulders of the cinematographers (Lotman 2021). This requires special skills of keeping the global view of the planned film as well as all so-far-acquired film material in mind, while being able to adapt to abrupt changes on the fly. As discussed before, de Borst and others (2016) initiated a line of study that focused on the ways in which cinematographers perceive and retrieve from memory (imagine) different types of cinematic images. Next steps could be to study how they predict spatial and causal events on the film scene based on their previous experience and ongoing contextual information.

In our view, familiarity with different film editing conventions may be added to the qualifications of a skillful cinematographer. Due to the systematic inquiries that have been carried out on the film form, film editors "have laid a groundwork for more refinements in theorizing that could benefit both scholars and practitioners" (Pearlman 2017: 68). Professional editors use terms such as "eye trace," i.e., an editing technique to direct the viewer's eye across cuts to the consecutive shots, listed in Walter Murch's rules of editing (Murch 2001), and "anchor point," which refers to the place in the shot that the viewer is focusing on. Keeping these points in close distance in two different shots helps to make the transitions between the shots smoother, because the viewer's eyes do not have to make a big jump. Awareness of the editor of these points where the eye fixates is the basis of the continuity editing style common in cinema. However, as Pearlman points out, it is not always a smooth cut that matters; it is also the momentary emotional feel of the situation of the character that the unfolding images convey to the viewer. We adapt Pearlman's idea of the editor's embodied expertise during the act of editing to correspond with the one that we think cinematographers also share: when shooting a film, cinematographers feel the rhythm and flow of the imagery through their own embodied perceptual skills, "their own eye movements, their own embodied simulation, and their own particular expertise in phrasing movement of images, emotions, and events" (Pearlman 2017: 84). In line with Tikka (2004, 2005, 2008, 2022), Yilmaz and colleagues (2023) and Gallese and Guerra

(2012, 2019), we trust that such embodied expertise is involved also when cinematographers view their own camera shots or shots by others.

The perceptual learning of cinematographers is based to a great extent on the past experiences of composing and viewing images in different contexts; consider, for instance, prevailing genre conventions of how to shoot a horror film or alternatively a romantic comedy. The perceptual professionalization also builds on the abilities to perceive (now) and predict (future) events in contexts (past). Thus, while learning cinematographic skills happens by doing, involving conscious decisions and actions, these processes also involve automated event-coding (beginning, middle, end) in the brain, consequent prediction of future events, and associated modifications based on prediction errors, in line with previous studies by Zacks and colleagues with non-professional test participants (Zacks et al. 2011; Zacks 2020).

Considering our aim is specifically to study cinematographers' perceptual learning, it seems crucial to focus on studying holistic "event cognition" (Zacks 2020) including the exciting knowledge of multisensory integration of the sensory qualities of temporally unfolding events with associated contexts and memory. Event cognition can be seen as twofold according to the Scene Perception & Event Comprehension Theory (SPECT) proposed by Loschky and colleagues (2020): (1) "Front-end processes occur during single eye fixations and are comprised of attentional selection and information extraction"; (2) "Back-end processes occur across multiple fixations and support the construction of event models, which reflect understanding of what is happening now in a narrative (stored in working memory) and over the course of the entire narrative (stored in long-term episodic memory)" (Loschky et al. 2020). The researchers ask, "whether and how back-end processes, including the current event model in WM [working memory], the stored event models in episodic LTM [long-term memory], and schemas and scripts in semantic LTM, influence the front-end information extraction and attentional selection processes" (Loschky et al. 2020: 318). A systematic review by Brams and colleagues (2019) concluded that the perceptual-cognitive gaze strategies detected in expert performance vary depending on the tasks. For example, the back-end processes in the SPECT model (Loschky et al. 2020) partially build on the long-term WM theory; when considering experts, it can be assumed that expert performers have developed memory skills that allow them to keep cognitive experiences directly accessible in LTM by means of retrieval cues in short-term memory (Ericsson, Kintsch,1995). Most of the expert studies reviewed mainly supported the information-reduction hypothesis, which suggests that "task-redundant information is ignored at a perceptual rather than [at] a conceptual level of processing" (Haider, Frensch 1999). However, medical experts in radiology were more lined with the holistic model of image perception proposed based on an eye-tracking study by Kundel and colleagues (2007): "The rapid initial fixation of a true abnormality is evidence for a global perceptual process capable of analyzing the visual input of the entire retinal image and pinpointing the spatial location of an abnormality" (Kundel et al. 2007). Considering the range of different tasks that cinematographers engage in throughout their career development, not only the perceptual, spatial, and causal aspects of the image under scrutiny matter but also the specific task and the overall context determine what type of perceptual strategies will best serve the expert performance.

While there is a lack of studies on the development of perceptual professionalization in cinematography, previous studies from other fields of expertise are available that bear witness to the results of such skill-evolution processes. For example, cinematographers' perceptual skills may be comparable to other expert skills that involve similar types of cognitive challenges for perceptual engagement, for instance skills that require anticipation of trajectories of objects and motivated goal-directed actions of other entities in specific contexts. Consider experts in the game of chess who have, since the early studies by Chase and Simon (1973), often been employed as a cognitive model for studying skilled perception of strategic objects and their spatio-functional interrelations (Langner et al. 2019: 74). Although expertise in chess and in cinematography might appear to be very different activities, in terms of perceptual skills they parallel: both involve analysis and anticipation of objects' temporo-spatial dynamics related to their coordinated movements that are apparently logical but may embody hidden motivations.

As cinematographers sometimes also physically move with the camera, their embodied experiences of these movements can be argued to be incorporated in the filmed images (Yilmaz et al. 2023). In this sense, also examples of physiological or bodily expertise from other fields, for instance professional athletes, may provide insights as to the perceptual skills of a cinematographer. For instance, the eyes of the players in ball-based games have been shown not to follow the whole trajectory of the ball in smooth pursuit; instead, after the initial release of the ball, predictive saccadic eye movements locate the ball's target position in advance of the ball itself (e.g. Bahill, McDonald 1983; in Aoyama et al. 2022). This prediction of physical trajectories could correlate to some extent with predictive inference of dynamically moving objects or goal-directed actions of agents on the screen. The prediction in the film case would depend upon "first constructing a mental model of the events, including establishing temporal and spatial relationships between the two events" (Loschky et al. 2015: 3). The question of what type of role such mental models or cognitive schemas play in the perceptual expertise of cinematographers is to be added to the list of relevant research questions for future studies.

It goes without saying that the closer the exploration of expertise in the previous scientific studies comes to the domain of actual filmmaking, the more relevant the findings. Especially, looking at how other filmmakers with different types of professional expertise describe their work methods is to be considered a fruitful resource of practice-based insights to the cinematographers perceptual learning processes.

For initiating what we envision to become a rich line of experimental studies on cinematographers' perceptual learning processes, we started with designing a qualitative study that would rely on visual observation of the gaze behaviors of a selection of cinematographers for providing us insights to these processes. We hypothesized that there would be differences in viewing patterns of moving images between film professionals with different experience levels in cinematography. We further hypothesized that recognizing these expertise-generated differences during the qualitative analysis process, we would need to involve team members with expertise in cinematography. Thus, one of our research foci was to find out, if in an eye-tracking study of perceptual professionalization in cinematography we involve cinematographers in the study design and in the interpretation of the results, could new insights be gained about the possible meanings of their peers' viewing patterns? If professional experts actively observe the temporal unfolding of the eye movements, they might be able to spot points or areas of interest, and thus contribute to the research with questions that are embedded in their lifelong professional expertise.

## CASE STUDY: VISUAL OBSERVATIONS ON THE GAZE BEHAVIOR OF FILM PROFESSIONALS

In the following we will report a qualitative eye-tracking study that was conducted to record and then visually observe the gaze behavior of volunteering cinematographers, cinematography students, and other film professionals. The study was expected to provide insights into the perceptual processes of cinematographers in different stages of their perceptual professionalization, working in different specializations under the cinematography department (e.g. cinematographer, camera operator, focus puller). The study was designed by a professional cinematographer (EL), who also collected and analyzed visually each participant's eye movements that were recorded on top of the stimulus video (see the subsection: Suggested gaze pattern analysis based on the qualitative findings). To the best of our knowledge, studies where filmmakers interpret their own eye-tracking patterns are non-existent. We trust that such engagement of filmmakers as both test participants and interpreters of their own data, collected in an experimental research, is one of the central innovations and contributions of our study to the future neurocinematics studies. The qualitative findings of this case study further informed us on how to proceed to the next experimental stages where we would collect both qualitative and quantitative data on the participants' gaze behaviors.

**Justifications for eye-tracking study**

Human eye movements and pupil size changes allow us to identify specific objects of momentary visual attention and combine this into a coherent perception of the environment (e.g. Irwin et al. 1990; Wolfe 1998). They also allow inferring to some extent embodied, cognitive, and emotional thoughts otherwise invisible for visual observation (Fiedler et al. 2020), albeit with limitations (see Orquin, Holmqvist 2018). In our study, we focused on visual exploratory behavior in situations in which participants were under generic instructions, a design of a preferential looking paradigm that is widely applied for understanding gaze behavior in natural settings (see Lima, Ventura 2023 for review). Furthermore, Loschky and colleagues (2020) provided us a theoretical framework in reference to different temporally unfolding gaze dynamics, related event perception, and their linkage to the dynamics of WM and LTM. While we advise readers to turn to the above-mentioned papers for more detailed descriptions of eye-tracking technologies, related study protocols, and gaze behavior dynamics, we define here some concepts that we use in the results section.

Eye-tracking (ET) refers to the registration of gaze movements in a subject's visual field. Collected data is quantitative and consists of gaze coordinates in time. Mapping the coordinates to the image of the visual field reveals the subject's point of visual attention at a certain moment of time. The current study involves following basic ET terminology: *fixation* – stopping the gaze on an object in the visual field; *saccade* – gaze movement from the previous to the next fixation; *area of interest* (AOI) – region/object in an image of visual field where the attention is of interest. Following basic ET metrics can describe general gaze behavior: (1) number of fixations; (2) durations of fixations; (3) lengths of saccades. The current study is mainly interested in visual attention to various objects, later to be defined as AOIs. There is a problem with defining AOIs in a video stimulus with moving cameras, objects, and actors. It would require defining AOIs manually frame by frame and matching the fixations with AOIs in the quantitative analysis also frame by frame. The current study uses an alternative method: qualitative gaze analysis of visual field video with gaze overlay (e.g., Figure 1). Here, the fixations at AOI are tagged manually in a video timeline and complemented with description of the gaze behavior of the participant.

An essential part of the ET procedure is calibration. Calibration is personal and allows precise mapping of gaze coordinates to a visual field image (screen-based ET in the current study is mapped to the screen coordinates). Calibration takes into account personal peculiarities of eyes, such as iris color, shape, and size of the eyeball, and effect of glasses or contact lenses. Calibration must be repeated with each participant. ET terminology and methodical explanations are based on the handbook by Duchowski (2007).

**Study design**

The study was designed to include the following: (a) a selection of moving images with a fixed duration (1'35"); (b) three groups of participants with different levels of perceptual professionalization; (c) annotations of the image contents; (d) qualitative analysis of the combined data from (a), (b), and (c) to identify any interdependencies (correlations); (e) interpretation of the analysis results in (d) in terms of levels of perceptual professionalism when comparing the three groups of participants.

**Groups**

A between-subject experiment with three participant groups was designed in order to observe the differences in terms of (1) the type of professional expertise (cinematographers and filmmakers who are not cinematographers); and (2) experience (experienced cinematographers and novice cinematographers).

**Participants**

The participants (8) were divided into the following three groups:

CP-group (3): Professional cinematographers and camera crew members with 10+ years of professional experience;

CS-group (2): Cinematography students from the BA curriculum (1st year) and PhD students (2nd year) who had graduated from the cinematography MA curriculum;

MP-group (3): Other media professionals from other fields in media with 10+ years working mostly in the field of audiovisual media editing.

**Stimulus**

In the experiment, participants viewed a trailer for *Empire of Light* (dir. Sam Mendes, cin. Roger Deakins, 2022, length: 1 minute and 35 seconds, comprising 52 separate shots). Sound was omitted to exclude its effects on the viewing of the image. The justification for using a trailer as a stimulus was that it would allow viewers to view multiple shots from one film in a relatively short time while its quick editing pace was expected to keep the attention of the viewers constant. The specific film was chosen because it was relatively new during the time of the experiment and the viewers would not be familiar with the video. This was to avoid previous experience affecting the viewing patterns.

**Procedure**

The participants were informed that they were taking part in a film-viewing study and that their feedback after the experiment would be encouraged. The participants were informed verbally that no data where their identity could be recognized was being collected or recorded during the study and that they could stop the experiment at any moment without giving any reason to the experimenter. Then the participants were seated by a table facing a computer screen; an explanation was given as to how the eye-tracker was calibrated and how to follow the instructions of the experimenter during the calibration. The calibration process was repeated until the tracking was deemed optimal. After the eye-track recording was started, the participants watched the test stimulus. No specific task was given; instead, the participants were asked to relax and watch the film as they would watch any other film in a non-experimental setting. After the viewing of the experimental stimulus (film trailer), the eye-track recording was stopped and the experimenter initiated an unstructured interview with the participant.

**Post-experimental free-form discussion**

The experimenter – a professional cinematographer – initiated a free-form discussion about the experiment, explained what had been measured, showed the participant's own eye-track recording, collected unstructured feedback on how the experiment setting had affected the viewer, and talked about the possible explanations for each viewer's eye-track idiosyncrasies, so that the viewer also could reflect back on them.

### Instrument
The experiment was conducted in a room with a laptop and an 24-inch external monitor that allowed recording eye movements when the selected film clips were playing so that the participants watched only the clip from the external monitor and the researcher watched a separate screen with eye-tracking. Viewers' eyes were scanned with the Mirametrix S2 Eye-tracker and the screen capture of the stimulus with the saccadic gaze tracks overlaid on it was recorded through Mirametrix Viewer software.

### Qualitative analysis
The aim of the analysis was to identify typical gaze behaviors while watching the stimulus. A typical gaze behavior includes a distinct sequence of fixations and saccades through meaningful points of attention. Such a sequence is also referred to as a *gaze pattern*. The cinematographer viewing the unfolding gaze patterns made notes about the idiosyncrasies of the specific viewers and, where relevant, asked specifying questions about atypical gaze behaviors.

## RESULTS

### Observations on expertise-related saccades
Qualitative visual analysis of the ET patterns on the video stimulus shows quite a wide spatial layout of the viewing patterns of all three – CP, CS, and MP – groups (**Figure 1**). There are also some differences between the MP and the CP/CS groups. For example, we observed differences in shots where there are two characters, one of them in focus and in the foreground, the other in the background and out of focus. Figure 1 shows possible differences in the ability to find different objects of interest and maintain them in visual WM. The shot depicts a passive, foregrounded, in-focus character in profile and the other, out-of-focus character in the background. The saccades of both the CP and the CS groups started from the foreground character and quickly found the background character, creating a pattern of a circle – starting from the foreground, quickly fixating to the background character, then returning to the foreground character. In the case of the MP group, there were two different ways of scanning the image: MP1 did not scan the background character at all and MP2 produced a pattern of quickly bouncing back and forth between the two characters multiple times (differently from the CP and CS patterns of one circle).

In a similar, but slightly different situation (**Figure 2**), the two characters were both active in the frame. The eyeline of the foreground character was suggesting an activity in the left of the frame, while an out-of-focus character in the background was leaning toward the right. These two directional elements created competition for attention on the opposite sides of the frame. In this case, CP participants exhibited eye-tracks that showed more ability to move between two possibly competing areas in the frame, while CS and MP participants' saccadic movements seemed to choose either one or the other area (either left or right from the central character).

Both Figure 1 and Figure 2 cases seem to have similar underlying causes of differences among the participants. We propose two possibilities of perceptual professionalization within cinematographers that can cause these differences: (1) cinematographers could be quicker at noticing different elements in the shot and analyzing the image, a behavior that can be visible in their saccadic eye movements; (2) cinematographers could be better at analyzing visual information, storing it in or retrieving it from visual memory (Loschky et al. 2020), so they don't need to scan back and forth too much to maintain the image.

### Observations on expertise-related predictive saccades
Another interesting finding was that the media experts (MPs) and the CPs showed more predictive saccades than the CS group (Figure 3). These saccades were defined as predictive because they moved

**CP1:**

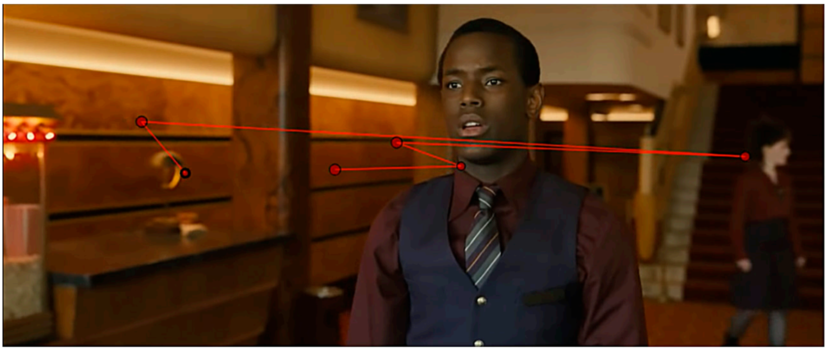
**CS:**

**MP1:**

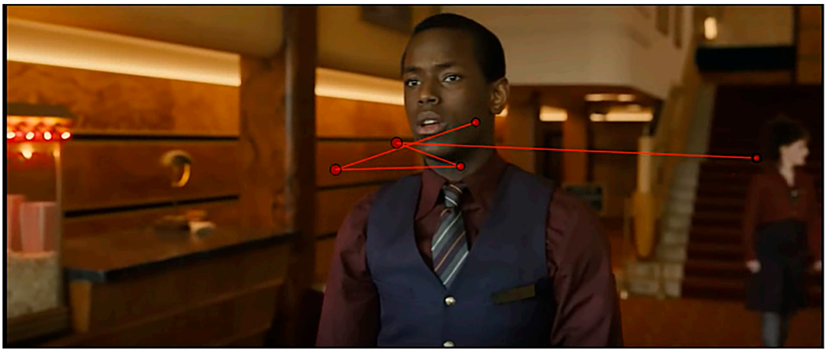
**MP2:**

**FIGURE 1.**

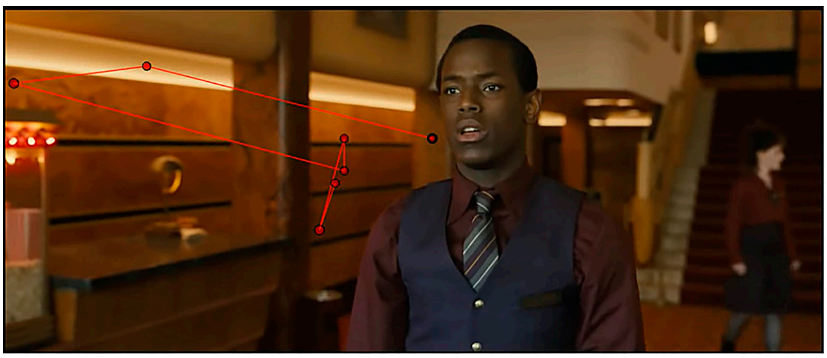
**CP1:**



**CP2:**



**MP:**



**CS:**

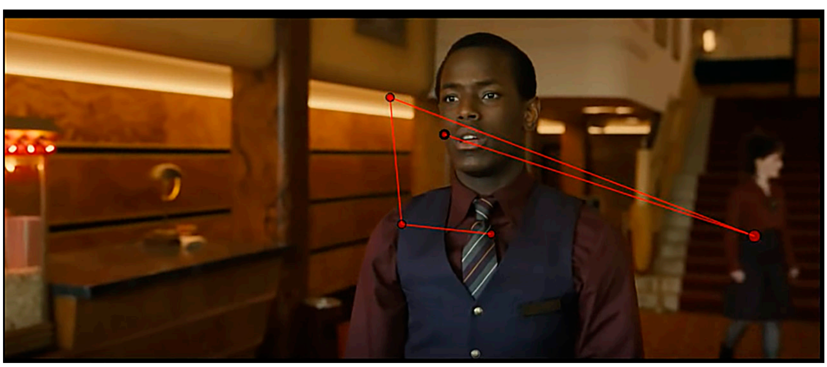
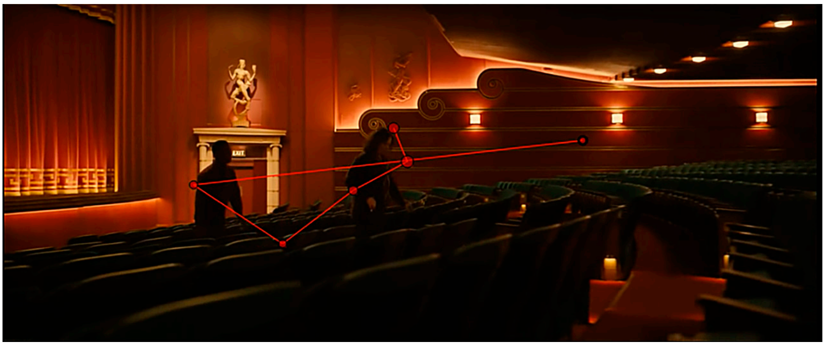
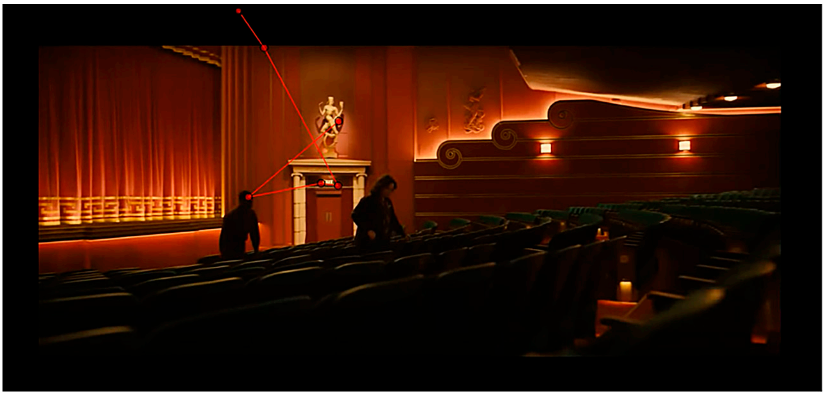


**FIGURE 2.**

**CP:**



**MP:**



**CS:**

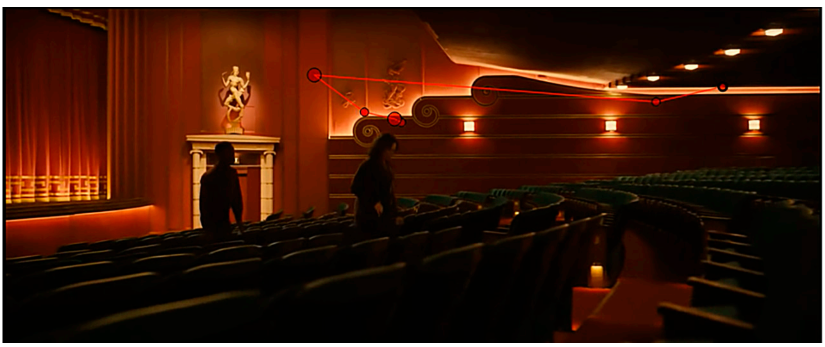


**FIGURE 3.**

in the forefront of camera movement or character movement or character eyeline direction.

**Figure 3**. Predictive scanning: the first two images are from the CP and MP groups, respectively, and the third image is from the CS group. All three find important objects quickly in the frame, but the CP and MP groups exhibit eye movements – suggestive of predictive saccades – that move in front of the characters (camera moves from left to right and both characters move from left to right, so the predictive saccades are the saccades that land far in front of the characters).

We can presume, based on the preliminary observations from our experiment, that film professionals, especially editors, use more predictive saccades in order to anticipate the ET pattern for the next cut. In line with previous studies on the eye movement of professional editors (e.g. Lieu 2020), our observations show that specific professional skills could be evoked in eye-movement patterns in general and in predictive saccading specifically. Consequently, our further question is, what are then the specifics of the eye movements of professional cinematographers?

## Observations on variations within novice and expert cinematographers

We observed some, quite slight, differences in CP and CS saccadic patterns (**Figure 4**). For example, two CP participants exhibited very wide saccadic scanning of a short shot with quickly moving objects, while a cinematography student (CS) with fewer years of experience did not scan the image so widely. We can presume that the reason for the difference was in the speed of scanning (as the shot was very short and in a quickly edited sequence); perhaps, if there had been more time for scanning the image, the CS viewer would also have produced a similar saccadic pattern. Hence, the level of professionalism here could be detected in the speed of scanning the global composition.

**Figure 4.** Global scanning. The first two images are global scanning by cinematographers with 10+ years of experience and the third image is a cinematography student.

## Observations on specification of variations in expertise within the cinematographers

One participant's ET scan exhibited a peculiar behavior: in a close-up shot of the main character, the saccades were fixed throughout the whole shot (size of the red circle shows the relative length of the fixation) to one of the eyes of the actress in the stimulus trailer (**Figure 5**). This ET pattern was present in only one CP. The same shot did not produce similar fixations in any of the other participants, who were also observing the face, but more laterally. This specific gaze was markedly fixed on one eye, which, due to the slight sideways position of the actress, was further away compared to the other eye.

**Figure 5.** Specific patterns – the first image shows the long fixation (the red eye-track is bigger, showing the length of fixation) of a focus puller and the next two images show how other professionals (MPs) scanned the same face.

In the post-experiment interview, the experimenter, based on her own tacit knowledge as a professional cinematographer, asked if the CP with the peculiar fixation to one eye works as a first camera assistant, also known in professional jargon as a focus puller. This assumption was confirmed by the participant – the main activity in professional work being that of a focus puller. As the job of a focus puller is to keep the crucial parts of the image constantly in focus and to adjust the focus as the scene moves along, common practice is to focus on points in the shot that match with the film viewers' presumed eye gaze patterns. From the focus puller's point of view, in a close-up shot with small depth of field the whole face cannot be in sharp focus, and thus the focus puller has to choose whether the focus is on the closer or the farther eye of the actor. Typically, focus pullers prefer to keep the focus on the farther eye (especially if it is combined

**CP1:**

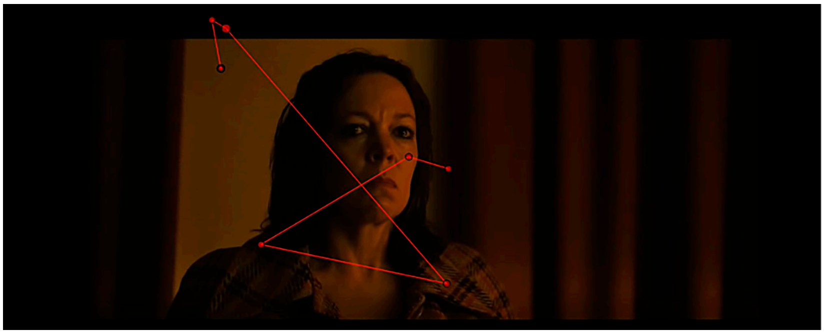
**CP2:**

**CS:**

**FIGURE 4.**

**CP3:**

**MP1:**



**MP2:**

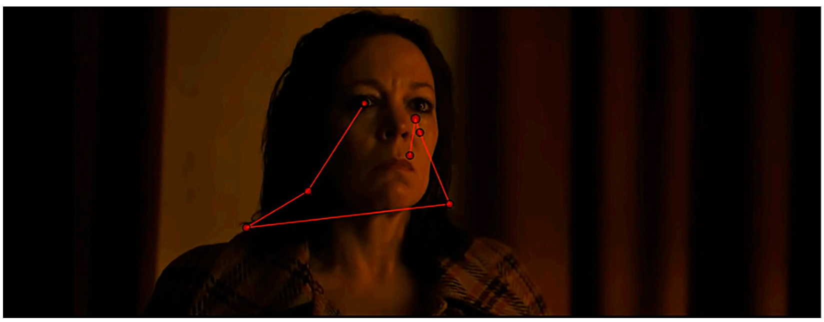


**FIGURE 5.**

with specific lighting patterns often used in films; for further details see Lotman 2016). Thus, the ET pattern of this specific case can be interpreted to reveal the gazing skills specific to focus pullers: looking at the farther eye to anticipate the actor's movement in order to adjust accordingly. In comparison with the other viewers, who scanned the whole face, the ET recording of this CP was remarkably different; thus, it might warrant further study that includes more focus pullers and close-up shots of static and moving actors.

Without the engagement of a cinematographer in the visual analysis, the specific ET pattern related to the focus puller expertise would probably have been interpreted as a random idiosyncrasy. This revelation supports our hypothesis of perceptual professionalization. The experimenter, who is also a professional cinematographer (EL), was able, while viewing the participant's eye gaze behavior on the screen, to create an assumption about what it could mean, and later in the post-experiment interview to confirm this assumption with the specific participant. We argue that this result could not have been obtained by quantitative data analysis alone. The interpretation by a professional cinematographer provided us with a type of information that otherwise would not have been discovered by researchers who were not familiar with cinematographic practices in general or focus-pulling practices in particular. Hence, we consider this to be the key finding of our case study that will carry relevance for future studies on cinematographers' perceptual learning.

**Suggested gaze pattern analysis based on the qualitative findings**

Qualitative analysis of the ET results revealed differences in the distribution of visual attention between experienced cinematographers and other media professionals. Due to the small sample size in our case study, all interpretations are tentative, requiring future validation with larger groups of cinematographic experts. In the following, we will draft a future experimental ET study between two groups, one of experienced cinematographers (10+ years of experience) and another of media professionals with no expertise in camera work (e.g. screenwriters). The following AOIs must be defined for the quantitative analysis: (1a) main character standing still; (1b) side character standing still; (2a) main character actively moving; (2b) side character actively moving; (3) character moving while the camera moves along; (4a) main character in the background with distinct objects (negative space); (4b) blank background with a distinct object without any characters; (5) background with many objects, where one of them dominates; (6) objects with visible activity in the background, e.g. light changing or moving.

The first part of the quantitative analysis would aim to describe the general gaze behavior during the stimuli by the number of fixations, average duration of the fixations, variability of duration of the fixations, average saccade length, and variability of saccade length. These metrics are expected to describe the peculiarities of individuals' visual attention. The second part of the planned analysis would focus on meaningful points of attention: the predefined AOIs. The following metrics of visual attention, as explained in detail by Duchowski (2007), are expected to describe the subjects' gaze patterns: (1) time to first fixation (TTFF) (time from the AOI appearing in the video till the first fixation in the AOI); (2) duration of the first fixation; (3) number of revisits (count of returning fixations in an AOI after fixated outside of the AOI); (4) dwell time in an AOI (total duration of fixations in the AOI); (5) sequence of visits when multiple AOIs are simultaneously present; (6) distribution of dwell time when multiple AOIs are simultaneously present. These metrics, calculated for all AOIs, would allow describing individual as well as group gaze patterns. Furthermore, they may allow confirming or rejecting the hypothesis of gaze pattern differences between cinematographers and other media professionals, as well as explain related details by comparing the means of all different metrics between the two subject groups. Moreover, the collected data would allow the use of cluster analysis in order to explore any other groupings of subjects beyond the intended experimental conditions.

**Summary**

The ET case study has provided us with novel insights into the planning of a major study on the perceptual professionalization of cinematographers, with the following findings: (1) preliminary support for our hypothesis that long-term professional practice can be detected in the eye movements of experienced cinematographers compared to novice students; (2) preliminary support for the assumption that ET patterns differ both within the cinematography department internally and compared with other media professionals (e.g. those who have mainly editing experience); (3) preliminary identification of challenges in the experiment design protocol and the selected ET method (see Fiedler et al. 2020 for detailed ET study guidelines); and (4) support for involving professional filmmakers throughout the whole experimental process, starting from the experiment design and continuing through to the data analysis and interpretation of the findings.

## DISCUSSION

While the perceptual learning process is broadly studied in psychology, very few studies focus on the perceptual professionalization of filmmakers or cinematographers in particular. Accumulated knowledge on the topic within other fields of expertise may serve as a fruitful starting point for identifying the specific in-group characteristics of professional cinematographers in contrast to those of novices. Identifying generalizable patterns of the perceptual dynamics of cinematographers during specific tasks such as operating camera movements could provide insights into their specific expertise performance, but they might also contribute to understanding more generally the embodied decision-making of cinematographers (Yilmaz et al. 2023). The challenge is that individual learning paths of perceptual professionalization are shaped by different personalities, artistic preferences, and social skills. Hence, each cinematographer relies on their own tacit knowledge when making creative decisions, the kind of knowledge Elen Lotman refers to as “experiential heuristics” (Lotman 2021). However, what we trust will help us to bypass these individual differences in future studies – at least to some extent – are the known interpersonal similarities in perceptual practices.

What professional cinematographers share as an expert group are the learned audiovisual film conventions and related patterns of cinematographic professionalism, particularly canonized by Hollywood films. Such widely applied conventions amongst professional cinematographers might include, for instance, how to move the camera in a horror film in contrast to a romantic comedy (Yilmaz et al. 2023). Or consider how the visual reinforcement of depth in a genre film may increase the feeling of empathy when compared to that of documentary films (Lotman 2016). Furthermore, differences in the levels of cinematographers’ perceptual skills could be analyzed in terms of data acquired from (1) time-coded film annotations, (2) related subjective reports, and (3) observations based on psycho-physiological measures, neuroimaging, and ET methods (Tikka et al. 2023). In order to proceed as suggested above, selecting the right, specific cinematographic conventions for the experiment becomes crucial when considering expertise-related characteristics of individual cinematographers’ creative processes within a broader framework of interpersonally shared film production contexts.

Our findings are to be viewed in the light of conducting future experiments, not as conclusive themselves, due to the small number of participants (8). One of the practical insights gained from the case study related to the participant recruitment. We realized that the group category for cinematography students did not work as expected, due to the fact that participating cinematography students from the film school had been preselected to study cinematography based on the skills they showed in visual tasks during the entrance exams, and they typically already had extensive practical expertise with image composition, video recordings, photography, and even shooting films. Thus, in future experiments the groups should be divided based on their experience, ranging from naive non-professional participants via groups of early stage cinematographers to groups of established cinematographers. Also, we inferred that different results in ET behaviors could be due to the specific camera jobs the participants mostly performed on the film production set. For instance, how the expertise of a camera operator differs from the expertise tasks of a focus puller may affect the way they scan the images.

What also will require consideration is, how clear can the borderlines of expertise be assumed to be between naive, initiated, and expert viewers that are invited to the experiments? Perhaps a range of cognitive expert viewing skills that relate to "perceptual learning" can be assigned not only to professionals but also to the non-professional persons who are habitually engaged with specific types of films and other mediated audiovisual content; for instance, sci-fi fans may learn peculiar details and narrative or visual patterns related to the films they are obsessed with that it may be argued approach the qualifications for expertise. From the experimental data analysis point of view, pre-experiment background information questionnaires of participants' audiovisual and film-related hobbies would allow detecting and omitting such statistical noise. In some cases, defining experiential borderlines of expertise may appear fuzzy between the filmfans ("cinephilia") and the filmmakers; consider film fans who know the horror genre films inside and out, and experienced cinematographers who start pre-production for their first-ever horror film shoot.

The stimulus of our study was the trailer for *Empire of Light* (2022), directed by Sam Mendes with cinematography by Roger Deakins, both filmmakers with multiple international awards. The film trailers genre is designed to attract the viewer's attention with cinematographically captivating images, fast edits, and enigmatic, provocative situations. Due to these qualities, trailers may allow differentiating the professional see'ers from non-professional participants; alternatively, their fast pace may forcefully override the professional features of viewing patterns and collapse the differences between naive and expert viewers to null, due to the "tyranny of film" hypothesis (Loschky et al. 2015). The trailer for *Empire of Light* was selected due to its high-quality production appearance, a characteristic that reveals the filmmaker duos' deliberate intentionality. With intentionality here we refer to a specific ability of filmmakers to enact artistic decisions through perceptual baseline heuristics (Lotman 2021: 89). Such skillful use of different visual tools, such as framing, composition, pacing, lighting, lensing, shot sizes, and so on, highlights what we have referred to as perceptual professionalism.

Should the choice for film stimuli rely on the cinematographers' best standards of what is quality film from their point of view? Or, perhaps the set of stimuli should include good, bad, and ugly films in order to secure variations between expert viewers and non-expert viewers. What about the role of motion? Could the gaze behaviors of non-professionals and professionals be better differentiated in their variations if the stimulus did not involve motion but called instead for individual mental inference processes (mind wandering), as was indicated by the findings of a study that involved naive viewers (Hutson et al. 2022)? These initial questions by no means exhaust the topics we should study in the future in order to increase our understanding of cinematographers' perceptual-cognitive processes. We trust that the design of the experiment, including the selection of stimulus films, cannot but benefit from the professional insights of cinematographers themselves.

## Benefits of perceptual professionality in research teams

Since the seminal paper by Hasson et al. (2008), studies in "neurocinematics" have accumulated new understanding on the embodied intersubjectivity of film viewing and today neuroscientific research groups regularly use films and mediated narratives as stimuli for studying human behaviors (Jääskeläinen et al. 2021). In our view, integrating professional filmmakers into the research teams would enrich the full procedural pipeline of study designs. This is so even when the goal of the research is on using films (only) as naturalistic simulation of life-like situations without more explicated artistic interests. In accordance with film editor Karen Pearlman, filmmakers have accumulated tacit knowledge through their practice that could contribute fresh perspectives to "scholarship in cognition and film" (Pearlman 2017: 68). Considering the research questions, the acquired data, and the validation of plausible interpretations from multidisciplinary points of view may help to reduce experimental artifacts and biases (Rosenthal 2009; Holman et al. 2015).

In the case that a set of multisource data is collected using several different methods – from established psycho-physiological methods that allow time-coded observations of film viewing to advanced interviewing methods that allow gathering similarly time-sensitive data on viewers' subjective first-person experiences – we argue that each of the methodic domains would benefit from film professionals' expertise. The engagement of a professional filmmaker could benefit the qualitative annotation of audiovisual stimulus material and correlation of these annotations with the quantitative data in terms of synchronized timepoints. When visually exploring ET data, filmmakers could differentiate gaze dynamics that relate to anticipation of future events from random eye gaze patterns, as in our case study findings. The predictive saccades suggesting such anticipation are dependent on multiplicity of dynamical film-specific elements that film professionals are familiar with based on their experience. A set of measurable characteristics of recorded eye fixations moment-by-moment would allow statistical comparison between different viewers; however, what a specific gaze location on the screen filled with dynamical elements and narrative actions implies could best be understood by employing the experiential heuristics of the filmmakers themselves. We may envision an experimental setting where filmmakers are involved both as test participants – whose neural and physiological behaviors are measured (as third-person, "objective" data) – and as interpreters of their own data (as first-person, "subjective" data) and the data of their peer participants (as second-person data here the target domain is shared due to shared knowledge or experience) (see Olivares et al. 2015).

So far a largely unexplored resource in the field of neurocinematics are the film schools where professional skills are acquired. Film schools provide a rich pool of both emerging and established professional filmmakers (screenwriters, editors, cinematographers, production designers, sound designers, etc.) with specific interest in teaching and research. We argue that film schools should join the efforts to raise new generations of professionals keen on understanding how the learned filmmaking methods, tacit practices, genre conventions, and related aesthetics affect their viewers. By promoting perceptual learning via experiential heuristics, the students would also learn how to exercise more agency within their own professionalization process.

## Limitations of the study and future directions

The reported preliminary study relied on qualitative visual observation of the ET recordings only, a limitation in its own right, the low number of participants being another limitation that constrained the analysis and interpretation of the results. As the data did not allow statistically relevant group analysis, the analysis focused on the idiosyncratic behaviors and related differences of the participants. Consequently, any shared cognitive processes of perceptual professionalization possibly linked to specific groups could not be identified. We are aware that only larger group sizes in future experiments would allow validation of the initial interpretations reported above.

In the future, all collected data should be annotated in terms of multiple variables and synchronized in order to further be correlated, differentiated, and controlled against. Annotation of the stimulus film (see Kauttonen et al. 2015) would allow correlating characteristics of the stimulus content (e.g. contrast, shot size/scale, color, movement, number of characters, anchor points, etc.) with related temporally synchronized ET data. Expertise-related variables could be the years of practice and the types of expert jobs (DoP, camera operator, focus puller, etc.).

An issue related to grouping the participants that we learned during our study was that cinematographer students may already have long-term expertise working with video and photography and thus in the future it would be beneficial to consider expertise in terms of years of practice only, and not in terms of study years at the film school. A longitudinal study that measures students during their entrance to film school and then revisits the same participants regularly over a number of years would allow seeing the above individual differences. Also, including non-cinematographers as a naive control group would allow capturing differences in those oriented to visual tasks compared to persons with no long-term visual hobbies or interests.

The calibration process before the experiment made the participants acutely aware of their eyes being tracked and several participants reported awareness of eye movement recording during the experiment. Such awareness of measures could have affected the results to some degree. We had to remove the data of one subject (9th participant) who explicitly mentioned having assumed that the “hidden” object of the study was to watch faces. In future experiments a clever decoy task that would not interfere with the viewing task could be a solution. The awareness of the ET is automatically induced in the calibration process; thus, it could perhaps make sense to plan a habituation period of a comfortable length of watching something else before viewing the actual stimulus clip. Finding a solution may require iterative testing before moving onwards with next experiments. As Fiedler and colleagues emphasize in their guidelines for ET studies, when designing an experiment attention should be directed “to reflect on the particulars of each study and make decisions with regard to methods and reporting that are justified by logical and scientific arguments, not by what previous researchers have done” (Fiedler et al. 2020).

## CONCLUSION

In this paper, we tentatively described the embodied perceptual learning processes of cinematographers that lead to what we call *perceptual professionalization*. We discussed a range of studies that show how professional expert perception differs from novice perception. An overview of the most recent neurocinematic observations provided background for how the perceptual learning of cinematographers could be studied using methods from the established film-viewing paradigms that so far have been focusing on naive viewers. To initiate what we envision turning into a rich line of experimental studies on cinematographers’ perceptual learning processes, we reported the first findings of visual observations from a qualitative case study. In this study we observed the gaze behaviors of professional cinematographers, cinematography students, and other media professionals when they freely viewed a film trailer. Variations between novice and expert cinematographers and between different cinematographic expertise were identified. These findings lay a path for further elaborations of study protocols and hypothesis formulations in studying embodied, experiential aspects related to the perceptual learning of film professionals.

We envision many interdisciplinary teams of researchers and practitioners joining the endeavor to unravel the embodied dynamics of the creative imagination, perceptual learning, and experiential heuristics of film professionals.

**AUTHOR CONTRIBUTIONS**

EL initiated and conducted the ET study and interpreted the results qualitatively. MM contributed to the design of the study and conducted part of the data analysis. All authors – EL, MM, and PT – contributed equally to the writing of the manuscript. Both EL and PT are professional filmmakers and cinematographers by training.

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ELEN LOTMAN is a filmmaker, teacher and scientist. As a cinematographer, she has shot tens of feature films, shorts and documentaries. Her films have won awards and have been shown in festivals including Camerimage, IDFA, Tampere, Black Nights, Goa, Manaki etc. Selected awards for the films she has shot include nomination for best cinematography at the ReelHeart in Toronto, a nomination for Camerimage Golden Frog, winner of the Black Nights audience award in 2021 and best cinematography in 2012. Lotman is an Associate Professor of Film Arts at the Baltic Film, Media and Arts School (BFM) of Tallinn University where she teaches future filmmakers. She defended her PhD thesis titled "Experiential Heuristics in Fiction Film Cinematography" in 2021. She has served as a co-president of the International Federation of Cinematographers.

MATI MÕTTUS is a lecturer and researcher in the School of Digital Technologies at Tallinn University. He defended a doctoral degree in computer science in the field of human-computer interaction on "Aesthetics in Interaction Design" (Tallinn University 2018). His current research interest is physiological and affective computing. The focus of research interest is two-fold. On one hand, the use of psycho-physiological signals in detecting human feelings while interacting with technology and explaining emotional behaviour, related to technology. On the other hand, the design of interactive systems is based on psycho-physiological loops and technology-related behaviours. Mati's recent activities include various projects in the areas of art & science as well as human interactions with industrial robots.

PIA TIKKA is a professional filmmaker and Research Professor at the Baltic Film, Media, and Arts School at Tallinn University. Tikka is a winner of the EU Mobilitas Pluss Top Researcher Grant (2017-2022) and holds the honorary title of Adjunct Professor of New Narrative Media at the University of Lapland. A former Director of Crucible Studio, Department of Media, Aalto University (2014-2017). She is the founder of the NeuroCine research group that studies the neural basis of storytelling and acted as a main investigator of neurocinematics at the Aalto School of Arts (2010-2017). She has published widely on the topics of enactive media, narrative complex systems, and neurocinematics. Her filmography includes international film productions as well as two feature films and interactive films she has directed. Currently, she leads her Enactive Virtuality Lab associated with the MEDIT Centre of Excellence, Tallinn University.