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Smartphone spectatorship in unenclosed environments: The physiological impacts of visual and sonic distraction during movie watching on mobile devices

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ABSTRACT

Smartphones' popularity is largely based on their pervasiveness, portability, and the wide range of functions they encompass: they can play high-definition moving-image content without spatial and temporal constraints. However, the lack of spatial and temporal frameworks can account for distractions. Distractions (generally sonic or visual information) can originate from the surrounding environment or from the device itself and they may or may not hold semantic links to the content being watched. In this paper, we argue that the distraction effect in movie watching is based on a distractor's modality, neutrality, and ecological relevance to the movie. To test the effects of these properties, we recorded viewers' gaze and electrodermal activity while they watched a narrative film sequence on smartphone and projector screens in the presence of sonic and visual distractors. We found that screen type can affect attention and arousal: in comparison to projector viewers, smartphone viewers experienced lower arousal and were more likely to shift their attention from the movie even when a distractor closely related to the movie was played. It was also observed that distractors that require urgent attention and are unrelated to the movie redirect the viewer's attention and increases electrodermal activity values. In contrast, distractors with ecological relevance to the movie are less likely to induce changes in attention and arousal.

1. Introduction

Among the numerous media platforms that offer movie or video experiences from cinema to personal screens, smartphones have gained increasing popularity. This popularity is perhaps based on smartphones' pervasiveness, portability, and the wide range of functions they encompass. This includes that they can play high-definition moving-image content without temporal and spatial constraints. Watching moving-image content on smartphones differs from traditional cinematic experiences in that the screen is smaller and is controlled manually and that viewing can occur in a variety of environments. In addition, screen size and viewing environments—which may include distracting stimuli—can affect oculomotor behavior, arousal, emotional engagement, and comprehension [39]. It has, however, yet to be determined how external (non-filmic) sound and visual effects impact smartphone viewers' engagement with a narrative film. The present paper investigates the impact of sonic and visual distractors of varying properties on attention and arousal to inform future research on mobile media and attention management.

1.1. Spectatorship on portable screens

Viewing experiences on smartphones are defined by the device's size and handheld use: it offers a small screen that can be taken anywhere and is controlled manually. Portable devices' technical properties have been shown to affect the viewing of narrative films—including attention, emotional reactions, narrative presence, and comprehension or recollection of narrative events [5,39]. These effects have also been investigated by comparing viewers' responses to content watched on stationary screens of different sizes arguing that smaller screens produce smaller visual angles that can impair engagement with an audio-visual stimulus. Notably, it was found that smaller screens or visual angles

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negatively affect arousal [29], self-reported presence [21,23,42], the completion of visual tasks [40], and the sensation of reality [20]. Studies of narrative film concluded that screen size affects gaze dispersion on the screen [35] and emotional engagement especially while watching particular types of content, such as scenes depicting human faces [42].

While research on movie viewers' reactions to content watched specifically on handheld screens is limited (as opposed to studies of small, but fixed screens), there is evidence that haptic control can increase the sense of engagement by involving the user's body and affording adjustments of the screen's position [22,45]. The latter point connects smartphones' handheld use to the question of interactivity: the possibilities for manual adjustments may cater to the personalization of viewing instances and adjusting them to environmental demands, such as moving the screen to obstruct potentially distracting external stimuli [38].

1.2. Distractions during movie watching

Based on the device's portable design, smartphone spectatorship can take place in a wide range of environments; at home, in transit, in a mall, on the street—to name but a few possible locations. The physical, social, and cultural frameworks of these environments, however, do not always afford uninterrupted and focused viewing. Unlike screening spaces, such as cinemas, that are designed specifically for watching movies, other environments and the related activities, habits, and sensory stimuli may distract from focused viewing and divide a viewer's attention between different sets of information. We label these external elements and stimuli as distractors.

Besides the surrounding environment, distractors can also originate from on-screen content: pop-up notifications, messages, and the like can divert a user's attention. Interruptive notifications have been demonstrated to have emotional and social effects [14,32], where smartphone users (often from younger generations) would focus their attention on pop-up message notifications in order not to miss out on crucial pieces of information or to avoid boredom. Although on-screen distractors and their social and cultural implications are out of the scope of the present paper, it is important to note that interruptive notifications can distract a focused viewing on smartphone screens: the sudden onset of a notification window and its content can divert one's attention to a movie.

We acknowledge that any screening technology and environment can include potential distractions, but due to the devices' properties and the habits of use, smartphones are perhaps one of those in use today that are most prone to involve distractions during movie watching. Despite this and smartphones' popularity, there are no sufficient conclusions on distraction effects in terms of smartphone spectatorship. However, we can base this research on previous studies that suggest that small screens can negatively impact arousal [29] and the sense of presence in a fictional narrative [23,28,34,42], which can lead to attention oscillation between the movie and other pieces of information.

According to a constructivist approach to the comprehension of narrative information, one perceives information that is, then, organized into clusters of meaning [3,48,52]. But this does not imply that only those pieces of information that originate from the primary source (i.e., a movie narrative) define comprehension. We hypothesize that sensory information acquired from external sources can appear as auxiliary information that may change interpretations. For instance, a sonic stimulus originating from the environment is perceived as relevant or apt to the movie, one may perceive it as part of the narrative. But if it lacks semantic links to the fictional actions or environments, they may distance the viewer from the narrative and become a distracting stimulus. This aligns with recent research on the perceptual and contextual links between sounds and other media [13,17].

In previous research, it has been established that when watching moving-image content, attention and emotional reactions are influenced by sonic information, including voice or sound effects, and visual information can provide a framework for sounds [8,36]. Moreover, the combination of sound and vision impacts emotional responses, generates anticipation, and influences meaning-making [2,10,46,47]. Studies also indicate the specific effects of sonic and visual distractors [39,53] and secondary tasks on narrative film experiences [43,51]—including the sensation of presence, emotional engagement, and comprehension. Notably, Zwarun and Hall [53] found that watching movies in a high-distraction environment (manipulated by the use of non-noise-canceling headphones, on-screen messages, and environmental noises) decreases comprehension accuracy and narrative transportation compared to a low-distraction environment and lack of external noises.

Although not directly applied to the case of movies or other complex audiovisual stimuli, research on completing visual tasks offers conclusions on attention and performance in the presence of sonic distractions [1,15,16]. In one of these studies, Escera et al. [16] found that acoustic information affects attention depending on its familiarity and relevance to a primary stimulus or task: an unanticipated sound would draw attention to itself and decrease task performance and increase reaction time. According to these findings, incongruent stimuli (such as unrelated sounds) divert participants' attention from the main task or primary stimulus. This leads to the assumption that stimuli unrelated to a movie can affect viewers' attention. However, it has also been demonstrated that a complex stimulus that demands a high perceptual load can counterbalance this effect: the more engaging a mediated environment is (e.g., in a video game), the fewer cognitive resources are available to be directed toward external stimuli, such as distractors [12,26,27]. These effects have not been demonstrated in comparison to screen types.

1.3. Classification of stimuli

Watching movies in unenclosed environments involves separating task-relevant (relevant to the movie) and irrelevant pieces of information. Yet, based on the aforementioned findings, we hypothesize that the source of information (whether it originates from the movie or not) does not necessarily define the amount of attention paid to it. Rather, we propose that attention and the related responses are determined by stimulus properties, namely its ecological relevance, magnitude, neutrality, and modality [37].

Ecological relevance indicates how much a stimulus is linked to a narrative or on-screen world. Magnitude (i.e., loudness or intensity) indicates a stimulus's source along with its degree of relevance and neutrality. The larger the magnitude (e.g., strong light or loud sound), the more prone a stimulus is to trigger attention. Neutrality (or urgency) presents a stimulus' contextual attributes that lead to intervention or reaction. For example, the sound of alarms or the sight of written texts are more probable to prompt action than abstract or static visual elements or background music. Based on these qualities, we argue that stimuli which do not directly originate from a movie or video would have different impacts on the viewing experience—including attention, the sensation of presence, and emotional engagement (see Table 1).

Stimuli that are irrelevant from on-screen content prompt bottom-up processing and capture attention through stimulus qualities rather than

Table 1
Classification of Stimuli.

Classification	Stimulus quality	Positive outcome (attention stays on the movie content)	Negative outcome (attention is shifted to the source of distraction)
Ecological relevance	Nature and meaning of stimulus	Related to the movie narration	Unrelated or irrelevant to the movie narration
Magnitude	Intensity (loudness, brightness, etc.)	Low intensity	High intensity
Neutrality	Response urgency	No immediate response required	Immediate response required

contextual information. While these may lead to little physiological reactions, ecologically relevant ones can urge attention shifts and are, therefore, more distractive. The same is true for complex and high-magnitude stimuli with high urgency.

1.4. The present study

Watching movies outside of designated screening rooms often involves stimulation from the surrounding environment and we argue that the likelihood of being distracted (attention being removed from the screen content) depends on a screen's immersive qualities: its size and position or the visual field it covers. While previous studies mentioned above touch upon the possible effects of distractions, little is known about these effects in the context of screen size and stimulus properties. To determine the impacts of sensory distraction during smartphone spectatorship, an exploratory laboratory experiment was designed in which volunteers watched a nine-minute sequence of a feature film either on a smartphone or a projector screen while sonic and visual distractors were played. During watching, we recorded participants' eye movements and electrodermal activity (EDA) to draw conclusions about attention and arousal. By measuring attention patterns, we aimed to assess whether distractors of certain properties would more likely divert viewers' attention from the movie than others and whether this effect depends on screen type. Emotional arousal was measured to evaluate how distractor properties and screen size affect the extent of being drawn into the movie narrative.

This study aims to draw conclusions about whether a distractor's ecological relevance, modality, and neutrality would play a role in attention patterns and arousal during watching a fiction film on a mobile or projector screen. In order to manipulate how distracting a distractor is, we used the variables of modality, neutrality, and ecological relevance to create distractors with high, medium, and low distraction effects. Using this experiment design, we address the following inquiries.

RQ1: How do screen type and distractor type affect the physiological indices of attention (eye movements) and arousal (electrodermal activity)?

RQ2: How does distractor condition (high, medium, low) affect the physiological indices of attention (eye movements) and arousal (electrodermal activity)?

From these research questions, we make the following hypotheses. Participants will demonstrate lower levels of distraction and higher levels of arousal when watching a film on a large projector screen compared to a small mobile device. We also predict that the type of distractor matters, where visual attention will be more likely to leave the film when the distractor is unrelated to the film (high distraction), compared to medium and low distractor types.

2. Methods

2.1. Design

To measure the effects of screen and distractor types, we used a two-by-four between-within design, with screen type (mobile screen and projector screen) being the between-subjects independent variable and distractor type (four distractors) the repeated (within-subjects) independent variable. Statistical power analysis using *G*Power* software indicated that a sample of 24 participants would be required for sufficient power ($\beta = 0.8$, when $\alpha = 0.05$) to detect a medium effect size ($f = 0.25$).

2.2. Participants

Thirty-eight volunteers, aged 24–37 ($M = 28.6$, $SD = 3.52$) took part in the experiment. Each participant was tested once in either the projector or the mobile condition. No exclusion criteria were applied other than having normal or corrected hearing and visual abilities, adequate knowledge of English, and at least two months of experience with smartphones and video player applications. Participants were recruited through academic and student organizations at [masked for review] University, and word of mouth. Each of them indicated their informed consent before the start of the experiment. Participants received compensation for their time.

2.3. Materials

Participants were asked to watch an approximately nine-minute sequence of a feature film, *The Walk* [50]. The sequence is set in New York City and on the top of the newly completed World Trade Center's towers, where the main character, Phillipe Petit performed a tightrope-walking act. This presents an urban environment with considerable traffic noises.

The movie sequence was chosen based on its relative obscurity yet up-to-date visual style and its capacity to maintain and control viewers' attention and engagement in an analogous way by featuring scenes with small shot duration and elements that prompt fairly universal reactions (e.g., animate objects, facial expressions) [7,11,19,24,30,36,49]. The sequence was also required to include elements that evoke strong emotional reactions to increase viewers' engagement with the narrative without featuring violent or disturbing content. While the sequence is unlikely to cause discomfort, it can evoke concerns for the main protagonist during his act and even moderate symptoms of acrophobia.

Quantifying environmental distractions, we played distractors at predetermined times. To maintain the possibility of surprise and avoid biases based on expectations, we limited the number of distractors to four sets that altogether covered approximately 10 % of the movie sequence's duration. Distractions in natural environments predominantly belong to the visual or sonic domain, therefore, we used two sound effects, one visual effect, and one that contained both sound and image. As shown in Table 2, the distractors were different in terms of ecological relevance, neutrality, complexity, and duration, and they had different source locations.

The first sound effect was designed as an external atmospheric cue to the movie and it includes some traffic noise bearing high ecological relevance to the scenes' New York City locations. Given its relevance to the diegetic space, the traffic noise distractor is used as a control condition with low distracting qualities.

The second distractor featured a ringing telephone with potential high ecological relevance to the environment where participants were tested—linking the distractor to their own mobile devices or the one that was used for the experiment. The phone distractor is considered medium distracting as it includes a non-verbal sound effect.

Providing high complexity and cognitive load, the third distractor was a written text (a Shakespeare quote) that gradually appeared against a plain background on a screen located on the front right-hand side of participants. This verbal and visual distractor had high distracting qualities: reading is automatic for literate adults and the movement (the gradually appearing text) is difficult to ignore. Given the high cognitive load reading requires and the lack of ecological relevance to the movie, we designed this distractor to model highly distracting circumstances.

The last distractor contained sound and image simultaneously: a sound of birds chirping and a dark-colored rectangle moving from one side of the screen to the other against a plain background on the external screen. The distractor combined urgent and neutral stimuli (the moving rectangle and the natural soundtrack, respectively) with no ecological relevance to the on-screen or the physical environments. Being a combination of sound and vision, this non-verbal distractor was included as an exploratory condition to examine the combined effects of distractors with different qualities.

2.4. Apparatus and setup

Two conditions (projector condition and mobile condition) were

Table 2
Types of Distractors.

Distractor		Stimulus	Ecological relevance	Neutrality	Time	Distraction condition
1	Sound	Traffic noise	Diegetic space	Neutral	7:15–7:29	Low distraction (control condition)
2	Sound	Ringing phone	Physical space	Urgent	7:41–7:52	Medium distraction
3	Image	Written text	Neither	Urgent	8:32–9:00	High distraction
4	Sound	Chirping birds	Neither	Neutral	9:01–9:10	Low and medium-high distraction (exploratory condition)
	Image	Animated rectangle	Neither	Urgent		

used to compare responses given to different types of distractors in different viewing settings. In the projector condition, we recreated theatrical or home cinema experiences, where viewers typically sit at a fixed distance from a canvas or screen. Common for smartphone spectatorship is the malleability of screen-to-eye distance, and thus, visual angle, so participants tested in the mobile condition held the screen in their hands and were permitted to adjust its position in a way they found comfortable.

Participants were tested in a dimmed and shielded experiment room. In the projector condition, a 47.3-inch (120 cm diagonal) canvas was used, with a distance of 180 cm from each participant. The sequence was projected with an 18.55-degree vertical and 32.4-degree horizontal angle with eye level approximately in the middle.

In the mobile condition, the movie sequence was played from a 5.5-inch smartphone (screen resolution: 1080x1920 pixels) running Android 6.0. The smartphone was set to airplane mode to avoid unforeseen distractions; luminance and sound volume were set in advance to correlate those of the projector condition. Participants held the device in their hands and were given the liberty to adjust the viewing angle between arm length and their eyes (approximately 60 cm). This resulted in an approximately 30–60 cm' viewing distance and a 6.49–12.93-degree vertical and 11.52–22.8-degree horizontal angle. For the movie's soundtrack, in both conditions, a pair of Sennheiser 400 headphones was used with no noise-canceling function.

Sonic and visual distractors were played from a separate screen and speakers. For the first distractor (traffic noise), a parametric (directional) speaker was used located at the back of the experiment room. The second and fourth sounds (phone and birds) were played from another, regular speaker in the frontright of each participant. Visual distractors (text and rectangle) appeared on a thirteen-inch external screen in the front-left of the participant. The luminance of the external screen was set to approx. 300 cd/m^2 to be bright enough to be sensed, even when it was out of one's visual scope. The screen covered a 9.53-degree vertical and 16.75-degree horizontal angle.

In both conditions, the movie clip and the distractors were synchronized using Presentation, a stimulus-presentation software by Neurobehavioral systems. This way, distractors went off at the exact same moment of the movie sequence for each participant. But while participants had no control over the playback of the sequence in the projection condition, mobile participants were instructed to start it on the phone they were holding. To avoid latencies between the eye tracking and EDA datasets, time triggers were sent to the measuring software at the beginning and the end of the movie sequence.

2.5. Measures

To measure eye movements, we used an SMI 1 head-mounted eye tracker (sampling rate: 30 Hz). This mobile eye tracker enables free and natural movements and can track both on– and off-screen gaze. To monitor participants' gazes leaving the screen at each distractor event, we recorded the frequency of fixations (gaze events of minimum 80 ms) that fell outside of the screen. The screen area was defined by a dynamic area of interest (AOI) set for each of the trials using the SMI's recording and analysis software (SMI BeGaze). Because of participants' head movements, the position of the AOI (x and y coordinates of the rectangle's four corners) was set manually frame by frame. The AOI enabled distinguishing among fixations on and outside of the screen.

Electrodermal activity was monitored through two finger sensors placed on each participant's non-dominant hand. The sensors were connected to a MegaWin ME6000 Biomonitor digitizer; data was recorded by MegaWin measurement software with a frequency of 1000 Hz (Mega Electronics).

To account for the high variability of EDA data among participants, we calculated the relative differences between individual baseline values (the average of 5000 data points recorded in the five seconds proceeding the movie clip) and the data points [4,6]. Relative difference values were calculated for each of the four distractor events.

2.6. Procedure

Before the experiment, each volunteer was given access to a short online survey to measure whether they have sufficient experience with smartphones and video players or need any special setups (e.g., setting correcting lenses for the eye tracker). Eligible volunteers (based on sufficient experience with mobile video) were assigned a time slot and a viewing condition (projector or mobile) to be tested individually.

Prior to measurements, each participant received an oral briefing and instructions. Then, we applied the eye tracker and the EDA skin sensors. A single calibration point was used to calibrate the eye tracker and in the case of a deviation of more than 0.5 degrees, we repeated the calibration with three points.

3. Results

The main dependent variables were calculated for each condition. Both the frequency of off-screen fixations and electrodermal activity data showed normal distribution. Due to technical errors resulting in insufficient data, three trials were excluded from the analysis of off-screen fixations and seven from the analysis of EDA. Excluded data is "missing completely at random" because data loss was related to randomly occurring technical failures [33,44]. To test the effects of screen size and distractions on attention and arousal, a Generalized Linear Mixed Model analysis was performed. The results of interactions and main effects are summarized in Table 3 and elaborated in the following sections.

3.1. Frequency of Off-Screen fixations

Fixations were recorded and the amount of those falling outside of the screen AOI at each distractor event was calculated. Results

Table 3
Generalized Linear Mixed Model, Interactions and Main Effects of Screens and Distractors.

Physiological reactions	Results		
	Interaction	Main effect of screen	Main effect of distractor
Frequency of off-screen fixations	$F(3, 132) = 20.97^*$	$F(1, 132) = 27.51^*$	$F(3, 132) = 47.54^*$
Electrodermal activity	$F(3, 116) = 1.92$	$F(1, 116) = 22.99^*$	$F(3, 116) = 3.00^*$

* $p < .05$.

demonstrated a significant interaction between screen type and distractors. Further exploration of interaction effects showed a significantly higher frequency of off-screen fixations for the mobile condition during the traffic noise (low-level) distractor (see Table 4), that is, viewers looked off the screen during the traffic distractor more when viewing the movie clip on the mobile than on the projector screen. During the text distractor (high level), the opposite tendency was observed in terms of screen type in favor of the projector condition.

In the mobile condition, the traffic noise distractor was associated with significantly fewer off-screen fixations than both the text distractor and the combined birds & rectangle (exploratory) distractor. In the projector condition, the text distractor produced the highest and the traffic noise distractor produced the lowest frequency of off-screen fixations, whereas there was no difference between the phone (medium level) and the birds & rectangle distractors.

In both conditions, the order of distraction effect from the lowest to highest was the following: traffic noise (low), phone (medium), birds & rectangle (exploratory, low and medium), and text (high). Although showing the same tendencies, the differences between distractors were smaller in the mobile condition (see Fig. 1).

3.2. Electrodermal activity

To identify event-related changes in electrodermal activity, relative differences were calculated between baseline values and the data points during distractor events (see above). As shown in Table 3, no significant interaction was detected between screen type and distractors in terms of EDA. A significant main effect of screen type was observed: EDA values were significantly lower for the mobile condition than the projector condition (see Table 5 and Fig. 2). EDA values also showed a main effect of distractor type, where values were significantly lower during the traffic noise (low level) distractor than during the text (high level) distractor and the combined birds & rectangle (exploratory) distractor.

4. Discussion

In this study, we investigated the impact of sonic and visual distractors on narrative film viewing using smartphones and stationary screens. Our results showed that screen types and distractors of different levels (modalities, neutralities, and extent of ecological relevance) can affect eye movements (attention) and electrodermal activity (arousal).

We investigated whether the effect of distractor type differed when measuring smartphone and projector viewers' attention and arousal. Off-screen fixations were the highest during the text (high level) distractor and lowest during the traffic noise (low level) distractor in both viewing conditions, however, the differences between distractors were more extreme in the projector condition. Although showing the lowest tendencies for off-screen fixations in both conditions, during the traffic noise distractor, mobile viewers were more likely to shift their gaze off the screen. According to these findings, mobile viewing was associated with more attention wanderings during the distractor with high ecological relevance to the fictional space. Given the results of previous studies that fixation points are more concentrated on the screen's central area in the case of small-screen viewing [35,39], we argue that the increased number of fixations leaving the screen (i.e., the stronger distraction effect of a low-level distractor) is related to a lower level of engagement with the movie narrative. Other previous findings further support this argument demonstrating the decrease of emotional engagement and immersion with the decrease of screen size [21,23,42]. Additionally, there is evidence that small-screen viewing and the presence of environmental distractions decrease engagement in comparison to uninterrupted large-screen viewing [39]. This suggests that if a distractor stimulus is semantically connected to the movie narrative (like our traffic noise distractor), less immersed viewing would increase the likelihood of attention wanderings.

In the case of the text (high level) distractor, we observed a different tendency: projector viewers' gaze left the screen area more frequently than mobile viewers' gaze. This distractor was classified as an urgent visual distractor with no ecological relevance to the diegetic or physical space yielding a high distraction condition. The fact that it prompted the opposite effect compared to the traffic noise distractor confutes the previous notion regarding screen size and requires further investigation.

In both viewing conditions, the text distractor prompted the highest and the traffic noise the lowest frequency of off-screen fixations. For both screens, our results revealed a noticeable effect of ecological relevance. We observed that distractors with low ecological relevance to the movie sequence (text and birds & rectangle) increased off-screen fixations compared to the distractor with high ecological relevance (traffic noise). Moreover, ecological relevance to the physical space (phone distractor) led to higher off-screen fixation frequency than that in the fictional space (traffic noise distractor) for projector viewers.

These results may be explained by a surprise effect similar to Escera et al.'s findings [16]: unexpected stimuli (in our case, those that lack ecological relevance to the fictional space) increase the chance of attention shifts and disrupt engagement with the movie. It is because it mobilizes a higher amount of cognitive resources for identifying its source, relevance, and the potential corresponding actions. Another explanation may be that those distractors that require a high amount of cognitive resources (involving higher distraction qualities) can be treated as secondary tasks, which can increase the likelihood of attention oscillation [43]. Overall, these results imply that distractors of different types may be more distracting depending on the type of screen.

While our data of arousal revealed no significant interactions between screen type and distractor type, it showed increased electrodermal activity values in the projector condition compared to the mobile condition. This is in line with previous results of increased arousal in large-screen spectatorship both in the presence and absence of distractions [39]. This may suggest that the arousal effect of distractors is the result of increased engagement with watching moving images on a larger screen corresponding to the higher level of immersion and emotional engagement demonstrated in previous research [18,23,42].

Comparing EDA values between the different distractors, we found that arousal during the traffic noise distractor was significantly lower than the text and birds & rectangle distractors, respectively. Accordingly, a neutral (non-urgent) distractor with ecological relevance to the diegetic space had a lower impact on arousal than urgent distractors with no ecological relevance.

A higher level of arousal in terms of audiovisual experiences can mean a higher level of presence and emotional engagement, and its decrease signals a reduced engagement or attention being drawn from the narrative [31,41]. This implies that distractors that produce high arousal likely draw viewers' attention from the movie causing attention oscillation and an increase in the frequency of off-screen fixations. Therefore, arousal serves as an index for distraction quality, where arousal during a distractor event negatively correlates with attention to the movie and positively correlates with the frequency of off-screen gaze. We partially demonstrated this tendency: the low-level distractor (traffic noise) yielded lower arousal and off-screen fixations than the high-level (text) and exploratory (birds & rectangle) ones.

Table 4
Frequency of Off-Screen Fixations Mean Values.

Distractor			Mobile		Projector	
	M	SE	M	SE	M	SE
Traffic noise (low)	0.04	0	0.07	0	< 0.001	0
Phone (medium)	0.16	0.06	0.16	0.08	0.16	0.08
Text (high)	0.90	0.08	0.32	0.11	1.48	0.12
Birds & rectangle (exploratory)	0.29	0.06	0.23	0.06	0.35	0.10
Screen type mean			0.20	0.04	0.50	0.04

Note: M = mean value; SE = standard error.

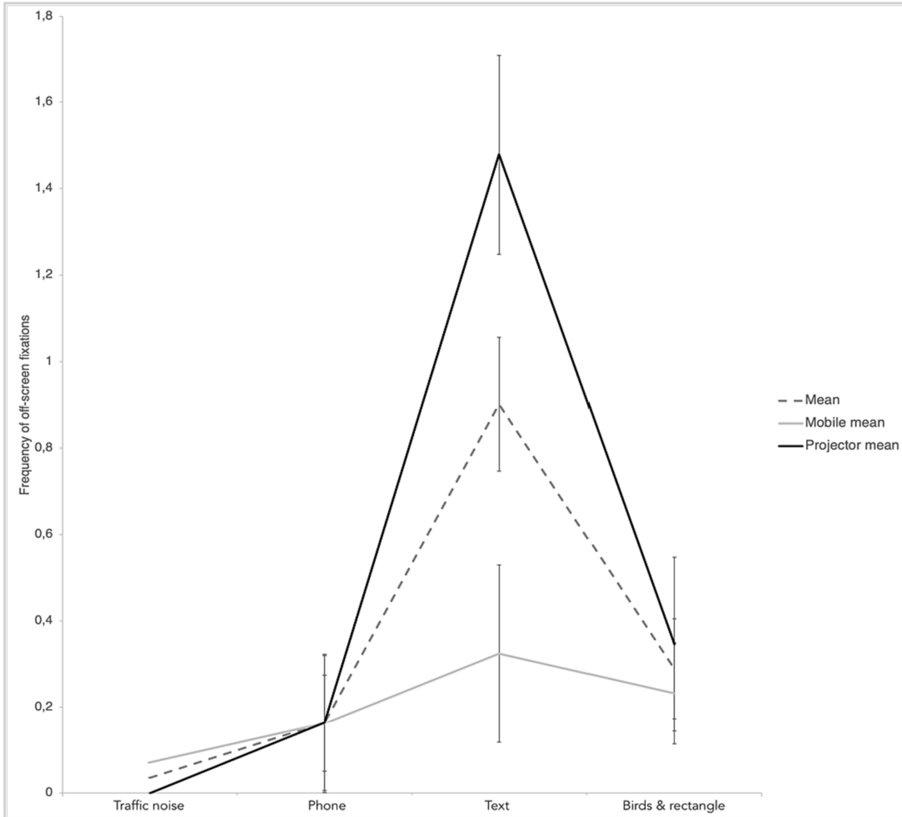

Fig. 1. Differences between mean values of off-screen fixations during distractor events. Error bars show ± 1.96 SE.

Table 5
Electrodermal Activity Mean Values by Distractor and Screen Types.

	M	SE
Distractor type		
Traffic noise (low)	0.05	0.02
Phone (medium)	0.09	0.02
Text (high)	0.09	0.001
Birds & rectangle (exploratory)	0.12	0.01
Screen type		
Mobile	0.05	0.01
Projector	0.12	0.01

Note: Since the Generalized Linear Mixed Model analysis showed no significant interaction between distractor type and screen type, only the respective mean values are reported. M = mean value; SE = standard error.

Our results showing an increase in electrodermal activity during urgent distractors with no ecological relevance would suggest a corresponding explanation to the off-screen fixation results. According to this explanation, the surprise effect of unexpected stimuli that have been identified to cause attention shifts and a decline in task performance [1, 15, and 16] would increase electrodermal activity values. This thesis is supported by conclusions on the physiological effects of surprise emotions: a surprise effect interrupts an ongoing action, reorients attention, and increases electrodermal activity [9,25]. This shows that off-screen fixations and arousal correlate in the case of distractors' ecological relevance, namely that the traffic noise distractor produced less attention wandering and lower electrodermal activity than any of the other distractors. This also suggests that environmental stimuli that are ecologically connected to the diegetic space can go unnoticed during movie watching, whereas urgent and unexpected stimuli likely prompt a reaction such as a shift in one's attention and increased arousal.

Our results demonstrated some effects of screen size and distractors' modality, urgency, and ecological relevance on attention and arousal. However, further investigations are necessary to establish the extent these effects depend on stimulus features, and whether they can be generalized beyond the specific primary (movie) and secondary (distractor) stimuli used here. Effects on viewing experiences were tested using distractors from external sources to model the effects of viewing environments. But we suggest that future experiments include on-screen distractors, such as pop-up notifications, as those are prevalent elements of smartphone use and may produce effects on viewers' attention. Further, follow-up studies with larger sample sizes are necessary to draw conclusions on distractors' effects on a wider user community.

5. Conclusion

In the present study, we measured viewers' gaze and electrodermal activity during watching a narrative film sequence on smartphone and projector screens in the presence of sonic and visual distractors. We found evidence that screen type can affect attention and arousal: in comparison to projector viewers, smartphone viewers experienced lower arousal and were more likely to shift their attention from the movie even when a distractor closely related to the movie was played. It was also observed that visual or multimodal distractors that include stimuli that require urgent attention and are unrelated to the movie or ongoing physical-world activities are associated with higher arousal and off-screen fixations, indicative of a surprise effect. In contrast, distractors with ecological relevance to ongoing activities (e.g., watching a movie) are less likely to induce changes in attention and arousal, although the extent of this effect can depend on screen type. While further studies are necessary to generalize these findings across moving-image content and types of external distractors, we confirm that stimuli of different properties impact physiological reactions and the amount of attention paid to them in different ways. These conclusions may contribute to future research on attention management in terms of mobile-device use and commercial materials' communication potentials

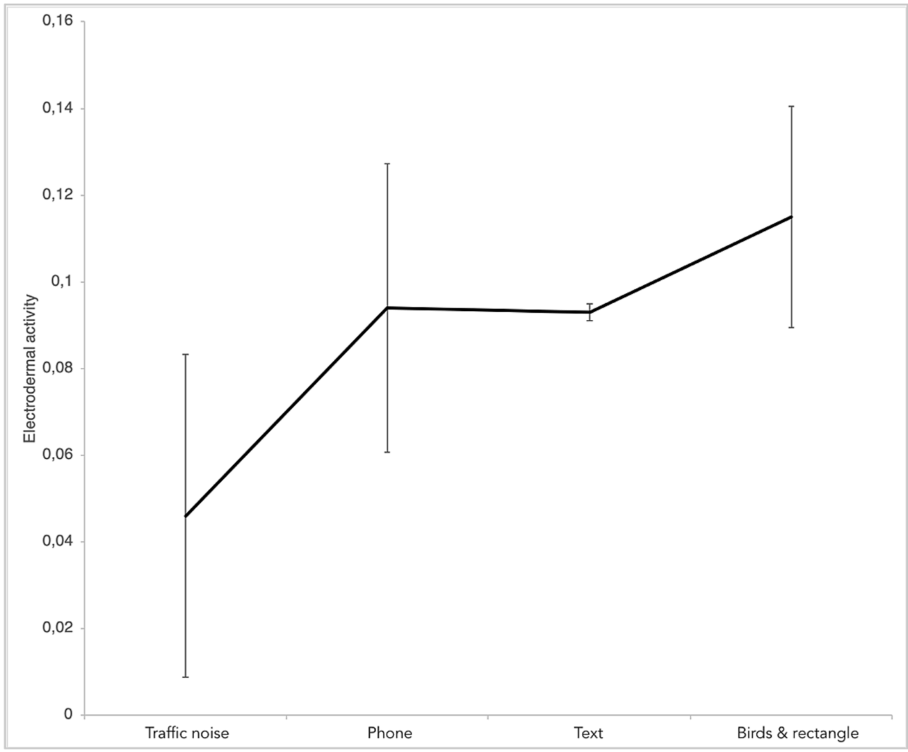

Fig. 2. Differences between distractor mean values of electrodermal activity. Error bars show ± 1.96 SE.

for smartphone users.

Research Transparency Statement

The authors are willing to share their data, analytics methods, and study materials with other researchers. The material will be available upon request.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix

Frequency of Off-Screen Fixations: Fixed Coefficients

Model term	Coefficient	Std. Error	t	Sig.	95% Confidence Interval	
					Lower	Upper
Intercept	0.346	0.103	3.370	0.001	0.143	0.549
Mobile*Distractor 1	−0.274	0.103	−2.673	0.008	−0.477	−0.071
Mobile*Distractor 2	−0.184	0.131	−1.398	0.164	−0.443	0.076
Mobile*Distractor 3	−0.022	0.147	−0.151	0.880	−0.313	0.269
Mobile*Distractor 4	−0.114	0.119	−0.962	0.338	−0.349	0.121
Projector*Distractor 1	−0.346	0.103	−3.370	0.001	−0.549	−0.143
Projector*Distractor 2	−0.182	0.130	−1.399	0.164	−0.440	0.075
Projector*Distractor 3	1.134	0.157	7.242	0.000	0.824	1.443
Projector*Distractor 4						

Electrodermal Activity: Fixed Coefficients

Model term	Coefficient	Std. Error	t	Sig.	95% Confidence Interval	
					Lower	Upper
Intercept	0.132	0.022	5.995	0.000	0.089	0.176
Mobile*Distractor 1	−0.140	0.035	−3.995	0.000	−0.209	−0.070

(*continued on next page*)

(*continued*)

Electrodermal Activity: Fixed Coefficients						
Model term	Coefficient	Std. Error	t	Sig.	95% Confidence Interval	
					Lower	Upper
Mobile*Distractor 2	−0.064	0.034	−1.886	0.062	−0.131	0.003
Mobile*Distractor 3	−0.084	0.022	−3.773	0.000	−0.128	−0.040
Mobile*Distractor 4	−0.035	0.026	−1.381	0.170	−0.086	0.015
Projector*Distractor 1	−0.033	0.035	−0.948	0.345	−0.102	0.036
Projector*Distractor 2	−0.013	0.032	−0.416	0.678	−0.078	0.051
Projector*Distractor 3	1.004	0.022	0.195	0.846	−0.039	0.048
Projector*Distractor 4						

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