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FRAMELESS

Evaluating Audience Engagement of an Immersive Performance on a Virtual Stage

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Abstract: *In this paper, we describe a methodology for determining audience engagement designed specifically for stage performances in a virtual space. We use a combination of galvanic skin response data (GSR), self-reported emotional feedback us ing the positive and negative affect schedule (PANAS), and a think aloud methodology to assess user reaction to the virtual reality experience. We describe a case study that uses the process to explore the role of immersive viewing of a performance by comparing users' engagement while watching a virtual dance performances on a monitor vs. using an immersive head mounted display (HMD). Results from the study indicate significant differences between the viewing experiences. The process can serve as a potential tool in the development of a VR storytelling experience.*

Keywords: *virtual reality, live performance, engagement, galvanic skin response, PANAS*

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INTRODUCTION

Since the early days of virtual reality (VR), the goal of presenting theatrical performances in virtual spaces has been an active area of exploration (Giannachi, 2004). This unique form of distributed storytelling is made possible through the use of distributed 3D worlds where actors, directors, and stage crew, all utilize the mechanics and processes of the theatre within the confines of the virtual space (Geigel, Schweppe, 2004, 39-46).

Traditionally, such works have been viewed on monitor-based systems such as Second Life (Rowe, 2010, 58-67) and VRML (Matsuba, Rochl, 1999, 45-51). The increasing popularity of head-mounted displays (HMDs) (e.g., Oculus, HTC VIVE), has expanded the possibilities for more immersive viewing of such works, and potentially expanding the overall audience experience.

The immersion enabled by these HMDs has shown great potential in improving the user experience for both film (Visch, Tan, Molenaar, 2010, 1439-1445) and games (Porter III, Boyer, Robb, 2018, 405–415). However, virtual theatre presents a unique user experience quite different from these venues (Geigel, 2018, 713-725). The question that motivates this work is: "How does the extra levels of immersion afforded by these devices affect the overall experience of the user viewing a theatrical performance in VR, if at all."

Assessing the user experience of such performances in exploring this question can be a challenge. Generally, there are two categories of methods that have been used in measuring audience engagement: explicit methods, which involves self-reported reactions using questionnaires, focus groups, surveys, etc., and implicit measures, which involve the measurement of biometric or physiological signals (Meehan, Insko, Whitton, Brooks, 2002, 645-652) recorded while watching the performance.

Each of these methods, taken alone, has their issues (Zimmermann, Guttormsen, Danuser, Gomez, 2003, 539-551). For example, self-reported questionnaires can only report on the conscious evaluation of affective state, whereas human affect is often an unconscious reaction. In addition, in many cases the evaluation is made after the fact, so comments are made on events that occurred in the recent past. Self-reporting during an event can skew the results as the experience is interrupted. However, the use of implicit methods requires specialized recording hardware and devices, which may be intrusive and affect the overall experience.

In our work, we have developed a process for evaluation of viewer reaction using both implicit means (bio-metric signals measured during viewing) as well as explicit measures (self-report questionnaires and think aloud). We then describe a case study that uses this methodology to explore the effect of immersive viewing by comparing audience reaction of watching a 3D virtual dance performance on an HMD with watching the same performance on a 2D screen.

ENGAGEMENT VS NARRATIVE ENGAGEMENT

In discussing our process and study, it is useful to distinguish between terminology used in the virtual reality (VR) literature with that used in the digital storytelling realm as aspects in the two disciplines share similar names, but have different shades of meaning.

The former describes aspects of a user experience when interacting in a VR application (e.g. immersion, presence, engagement) and is independent of any story (Slater, 2003). The latter considers users involvement specifically with the narrative and describes characteristics of narrative engagement (e.g. narrative understanding, attentional focus, emotional engagement, narrative presence) (Busselle, Bilandzic, 2009, 321-347).

We utilize existing VR terminology (Slater, 2003), specifically using the term immersion to relate to the level of sensory fidelity presented by the various devices of a VR system. Immersion is solely dependent upon the devices (visual, aural, and interactive) and hardware that make up a VR presentation system.

This is in contrast to presence which describes a user's feeling of "being there." It is important to note that presence, unlike immersion, describes a user's perceptual response to a VR experience. Using an immersive viewing platform like an HMD can clearly contribute to the feeling of presence (Busselle, Bilandzic, 2009, 321-347), (McMahan, 2003, 77-78) but the terms are not synonymous, as immersion relates to technology and presence relates to a user's response to that technology.

Presence and narrative presence are somewhat related as they both describe levels of removing oneself from one's actual mental surrounding. Whereas VR presence is locational, narrative presence describes being lost in the story. One can describe this comparison as losing awareness of one's surrounding (VR) vs. loss of awareness of oneself (narrative) (Busselle, Bilandzic, 2009, 321-347).

Finally, engagement in the VR world describes focused attention and emotional response to an experience. Engagement has more to do with how the content affects a viewer or participant. Engagement can be used to examine presence, but they differ as one can be present without being emotionally engaged, and vice-versa (Slater, 2003). This aspect is more related to the emotional engagement and attentional focus characteristic of narrative engagement.

In our work, we focus on audience engagement (in the VR sense), when viewing a performance on a virtual stage and the effects that immersion, achieved by utilizing an HMD, has on that audience engagement. We are less interested in presence, though it is understood that any differences in engagement may indeed be affected by underlying changes in presence. We also do not measure narrative engagement directly, but note how VR engagement might contribute to the determination of narrative engagement.

MEASURING AUDIENCE ENGAGE-MENT

Live Performance

In developing a method for evaluating audience engagement, we looked specifically at means used in evaluating responses to live performance for motivation. In this context, prior relevant works have involved applying a combination of both implicit and explicit measures, typically correlating implicit measurements with the self-reported reactions.

For example, studies have used brain-computer interfaces to compare electroencephalogram (EEG) signals during live performance with responses of post-performance questionaires (Yan et. al., 2017, 1-28), (He et. al., 2018, 1-11). Electromyography (EMG),

which measures low-level muscle activity of the arms (Sanchez, Zelechowska, Jensenius, 2018, 1-4), and the use of audience movements such as facial expressions, hand motion, and gesture, have also been explored (Theodorou, Healey, Smeraldi, 2016, 1-7).

In our work, we use galvanic skin response (GSR) signals, which gauge excitation of the sympathetic nervous system. GSR signals measure electrical skin conductance and have shown to be an effective indication of human affective states (Hassib, 2017) Not only is the collection of these signals less intrusive than other measures, but more importantly, there is some precedent in using GSR, particularly when gauging response during a live performance, with researchers finding a positive correlation between audience engagement and GSR signals (Latulipe, Carrol, Lottridge, 2011, 1845-1854), (Wang, Geelgoed, Cesar, 2017, 1-10), (Wang, Geelhoed, Stenton, Cesar, 2014, 1909-1912).

PANAS

For collecting self-reported response to the performance, we chose the Positive and Negative Affect Schedule (PANAS) as a measurement instrument.

PANAS (Watson, Clark, Tellegen, 2988, 1063-1070) is a psychometric scale consisting of twenty emotions, broken into positive and negative emotions. Both categories contain ten emotions each that subjects rank on a five-point Likert scale. PANAS aims to measure how the subject is feeling when they participate in an experiment. It is often used to measure change in a subject's affective reactions; administering a pre-PANAS to assess their emotions coming into the experiment and a post-PANAS to evaluate the change the stimuli had on the subject.

We chose PANAS over other standard questionnaires such as the Presence Questionnaire (Witmer, Singer, 2998, 225-240). Social Presence in Gaming Questionnaire (SPGQ) (Kort, Ijsselsteijn, Poels, 2007, 195-203) and the Virtual Experience Test (VET) (Chertoff, Goldiez, LaViola, 2010, 103-110), as these data collection instruments are designed to gauge presence in virtual reality and, as previously mentioned, we are more interested in assessing emotional engagement rather than presence. As PANAS is not specific to VR and is designed to measure emotion independent of application, it is a more appropriate instrument in this study.

METHODOLOGY

In this section, we describe our study methodology, which uses GSR data as implicit signals combined with PANAS as an explicit measure. The full overview is outlined in Figure 1.

Fig. 1. The process followed for each subject in the experiment included six main steps, from preparing the experiment and administering pre-viewing questionnaires to closing questionnaires.

Due to the self-reporting nature of PANAS, the peak-end theory, which suggests that people's self-reports will be based on the most extreme peaks of arousal during and at the end of an experience (Braithwaite, Watson, Jones, Rowe, 2013, 1017-1034), raises questions about our post-PANAS results as the survey is taken right after our experiment.

To address this, we supplemented PANAS with real-time reporting through a think aloud data collection. This allowed participants to speak about their experience during a consecutive second viewing to capture the neglected data in PANAS.

Four questionnaires were administered: two before the performance viewing and two after. The pre-performance instruments included a short demographic survey, and a pre-PANAS survey. In the pre-PANAS survey, participants were asked to rate their emotio ns based on how they felt in the past week.

Next, the participants watched the performance, during which, GSR signals were collected during viewing. After a short intermission, subjects viewed the performance for a second time where we conducted the think aloud task. For this second viewing subjects were instructed: "You will now view the same performance again. Describe how the piece makes you feel in real time. This includes notable moments, vivid emotions, and general comments about the piece." We collected the think aloud data as speech recordings, which were later transcribed.

This second viewing enabled us to independently capture meaningful GSR and think aloud data. Best practices in the use of GSR data suggests subjects not talk during data collection as speaking may elicit slow variations in the signal not related to emotional arousal (Braithwaite, Watson, Jones, Rowe, 2013, 1017-1034). Furthermore, the first viewing gave subjects a chance to view the performance without the additional stress of reflection during the think aloud task.

The session concluded with a post-PANAS survey where subjects were asked to rank the same emotions on how the dance performance made them feel, followed by a set of reflection questions as indicated below:

Q1: What drew your attention or stood out to you during the performance?

Q2: Did the VR headset or the computer screen add/subtract from your experience?

Q3: What did you notice about your perspective point? Did you notice it?

CASE STUDY

In order to explore the effects of immersive viewing, we employed our methodology and conducted an IRB-approved user study whereby two groups of participants individually viewed a dance performance in virtual reality: one group on a computer monitor and the other through an Oculus Rift (https://www.oculus.com/rift/).

To measure GSR, we used a Shimmer3 sensor (http://www.shimmersensing.com/products/shimmer3-development-kit) attached to the subject's fingers as recommended in previous studies(van Dooren, De Vries, Janssen, 298-304, 2012), as shown in Figure 2.

Fig. 2. Shimmer3 device used to capture and record GSR signals from subjects.

This work uses *Farewell to Dawn* (Geigel, 2018, 713-725) as an exemplar of virtual theatre. *Farewell to Dawn* is a live dance performance, accompanied by instrumental music, that combines virtual and augmented reality, with real-time motion capture. The dancers in the virtual space are guided by motion-captured dancers in the physical world and represented in the virtual world as stylized avatars comprised of a set of red or blue point lights. The five minute dance takes place in front of a typical European cafe in the virtual space, as seen in Figure 3.

Though originally performed live, the motions of the live dancers have been recorded and played back in real time for the sake of our study. The VR experience was created using Unity3D and played back using a PC with a GTX Titan 10 GB graphics card. For music playback, external headphones were used during monitor viewing and the Oculus Rift's built in headphones were used during immersive viewing.

For non-immersive viewing, we looked to emulate an environment typical when using distributed 3D virtual worlds such

Fig. 3. Screenshot from "Farewell to Dawn." Dancers are represented by stylistic, point light avatars. The inset shows a live dancer controlling the avatar model. The futuristic heads represent audience members viewing the performance in an HMD from the perspective of sitting at the table on the virtual stage.

as Second Life. As such, viewing was done on a standard 20" flat screen LCD monitor in average interior lighting with covered windows to avoid the effects of outdoor sunlight and weather.

16 participants viewed the recorded live performance in the Oculus Rift, while the remaining 16 participants viewed it on a computer monitor. Information of subjects' distribution by sex and viewing platform are in Figure 4. The experiment took place on an university campus. The mean age was 22, and ages ranged from 18 to 46 (s.d. 4.35).

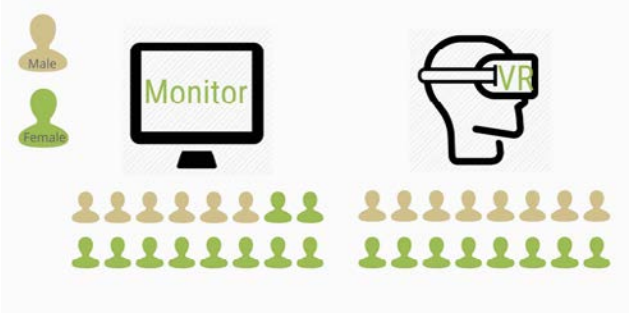

Fig. 4. The graphic provides information of self-identified sex and performance platform viewed for the subject group (N=32 total subjects).

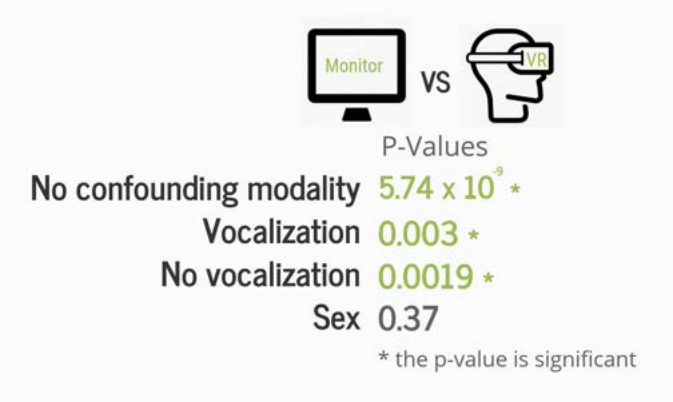

Fig. 5. P-values for statistical tests on GSR values. Significant differences in overall mean GSR between monitor and HMD viewing were found as well as over periods of vocalizations (times during which subject spoke in second viewing) in comparison to non-vocalizations (times during which subjects did not).

RESULTS AND DISCUSSION

GSR

To account for individual differences in GSR measurement sensitivity between subjects, the change of GSR from an individual's baseline was used when analyzing GSR data. We defined the baseline for an individual to be the GSR reading right before the start of the performance. Two-tailed t-tests on the mean of the GSR signals were performed as described below. A summary of the p-values is presented in Figure 5.

Considering the overall experience (no confounding modality), we found a significant difference of the mean GSR between HMD and monitor viewing measured during the first viewing of the performance with a p-value of almost zero.

Additionally, when considering time periods when participants spoke during the second viewing to the corresponding time periods during the first, our findings did indicate that mean GSR for subjects, regardless of platform, had a significant difference over periods of vocalizations (times during which subject spoke) in comparison to non-vocalizations (times during which subjects did not speak) with p-values of 0.003 and 0.0019, respectively. The positive relationship between GSR readings during the first viewing and vocalizations during the second suggests potential in future uses of this combined methodology to identify memorable moments, which we define as particular significant events that stand out collectively to viewers, during a performance.

Moreover, we performed a time-based analysis to see if we could determine particular points during the performance where engagement differed between monitor and immersive viewing. The data, from GSR and time stamped think aloud utterances, did not suggest particular times or events during the performance for which there was significant commonality between participants for either modality. This was not surprising given that the performance itself was subdued and had no major changes in mood. Finally, we found no significant effect of self-reported sex on GSR signals.

PANAS

PANAS was administered before and after the experiment, allowing us to measure the change in emotions experienced from viewing the dance performance. Two-tailed t-tests indicated statistical significance across viewing platforms with at least a confidence value of eighty percent for some of the emotions. An overview of findings for emotions that exhibited significant differences is in Figure 6 with a summary of the findings in Figure 7.

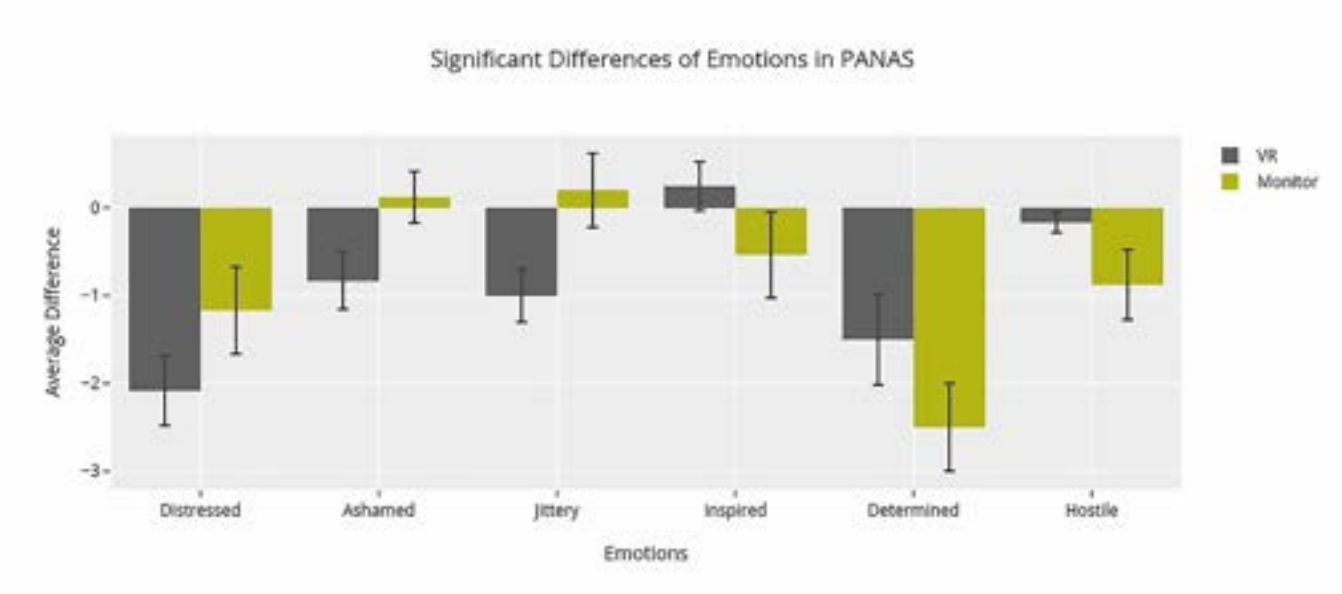

Fig. 6. PANAS considers 20 emotions, 10 positive and 10 negative, to determine the overall emotional state of a subject. We administered PANAS at the beginning of the experiment and the end to capture the changes in emotion that the dance performance invoked. Here, emotions that exhibited significant differences are included.

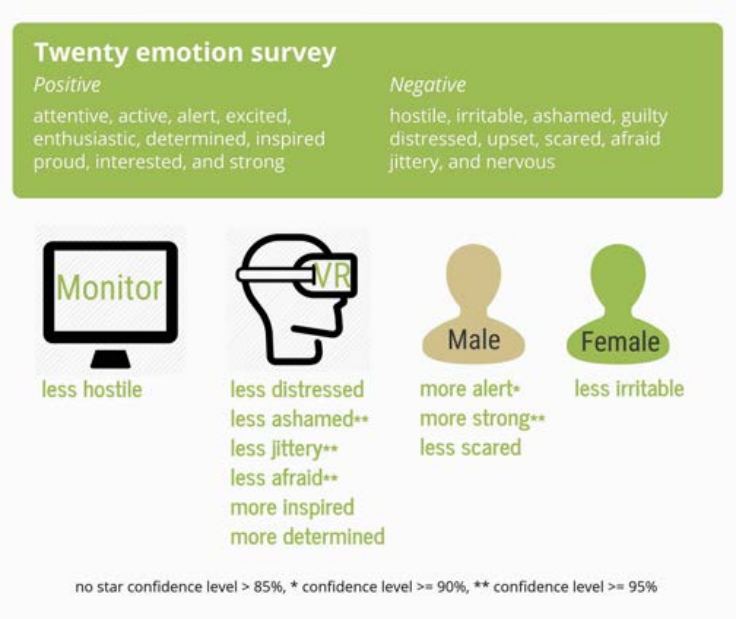

Fig. 7. Summary of PANAS emotions with significant differences between viewing in an HMD and viewing on a monitor. The use of two-tailed t-tests found changes in these emotions to be significant, in contrast to self-reported sex.

Our results show that the self-reported perceptions from PANAS demonstrate a significant difference in the viewing modalities. The immersive platform had a more positive experience than the monitor platform as they were significantly ($p < 0.5$): less ashamed, less jittery, and less afraid. In addition, we found one significant difference in PANAS results between self-identified male and female subjects. The males had one significant positive emotional difference over females: being stronger. This suggests that demographics can alter subjects' experiences with the medium, and these differences are a limitation of our work.

Second Viewing – Think Aloud Comments

In analyzing the comments made by participants during the second viewing, no statistical commonalities between the viewing modalities were found. However, several observations of the comments are worth noting.

Four out of the sixteen subjects viewing through the HMD made mention about the music making them want to move: "*The drums are cool, and they like they kind of make me want to tap my foot along with it; This [music] makes me want to get up and dance with them [avatars]; It's pretty high energy. Makes me want to move; and, this type of music makes me feel excited or, I don't know, very upbeat like I want to dance to it.*"

In contrast, no monitor subjects spoke of wanting to dance. When monitor-viewing subjects do mention the figures dancing, they were either confused or reflected fondly on it, but they did not report feeling a call to action. For instance, a subject in the monitor condition said, *"Again, I'm just happy. Enjoying what I am seeing. Looks fun, energetic." A subject in the monitor viewing said, "Those little white things [the futuristic avatars at the table on the virtual stage] are super weird. They keep grabbing my attention even though I know I am supposed to be paying attention to the sparkly things [dancers]."*

The comment from the latter subject suggests a focus on the technical aspects of the presentation: how the graphics were generated and the nature of the audience viewing from the virtual stage. This suggests that both platforms experienced engagement in different ways; monitor viewers seemed less present in the environment, so they sought to understand the technical aspects they saw, whereas the HMD participants' spoken experiences lead us to believe that this was not the case for them.

Reflection Analysis

In analyzing the post-viewing reflections, we used the Microsoft Azure's Cognition Services Text Analytics API to generate key phrases from subjects' answers to the three reflection questions. The key phrases gave insight to the common experiences among HMD and monitor experiences.

For Q2 and Q3 (above), key phrases were similar between monitor and VR participants. They were also words relating to the question itself like *monitor, VR, experience*, and *perspective*; however, Q1 showed a difference between the two platforms and a shared common experience within the platform. HMD viewers mentioned *figures* and *people*, while monitor viewers *mentioned attention*, *performance, time,* and *changing*; see Figure 8. This indicates that the HMD experience allowed subjects to notice and tune in the dancing figures, while the monitor subjects had a more broad perspective on the experience.

Fig. 8. Key phrase results from Microsoft Azure yielded interesting differences between VR and computer monitor subjects for the first question of the reflection.

CONCLUSION

In this work, we presented a methodology for assessing user experience of a performance presented in virtual reality using both implicit (GSR) and explicit (PANAS/ talk aloud) means. We employed this methodology to explore the effects of immersion on viewing a dance performance on a virtual stage and found significant differences between viewing in an immersive HMD versus on a computer monitor.

Results from our case study showed significant differences in GSR measurements based on viewing platform, as well as based on pre- and post-PANAS measurements, that subjects in the virtual reality environment had a more positive experience than those viewing on the computer monitor. Feedback obtained via the think aloud and reflection analysis also emphasized differences between the two viewing scenarios.

Although the study evaluated a particular artistic work, the methodology of the study provides a foundation for conducting similar studies. The combination of PANAS, reflection, and the think aloud methodology in conjunction with GSR data constitutes a novel approach in the study of live performance in virtual reality. The approach is also extendable to include other implicit measures such as the viewer's pulse.

While it considers only one aspect of narrative engagement, determination of audience engagement, could potentially be used as a quantifiable resource and tool in narrative development and in designing storytelling experiences.

Our findings also suggest, when evaluating future storytelling experiences like a virtual theatre dance, that moments at which viewers chose to speak during the second think aloud viewing were particularly engaging for that individual during the initial viewing. Experience developers can take away that participants may be more likely to keep engagement on the center of the plot--for us the dancers--instead of focusing on the design of the experience. Statistically demonstrating this was outside the scope of our project, but is a good direction for future research; along with evaluating how the more positive sentiments seen in VR participants, as assessed by PANAS, could have helped aid this effect.

Accurately measuring audience reactions to a live performance is a complex process and an active area of research in the theatre arts community (Radbourne, Johanson, Glow, White, 2009, 16-29). This study used general survey instruments (e.g. PANAS) to gauge audience response. A future study could use this setup with a more comprehensive evaluation metric aimed specifically

for theatrical events (Tung Au, Ho, Wing, 2017, 27-46), (Chan, Au, 2017, 169-193), or one that addresses narrative engagement more directly (Roth, Koenitz, 2016, 31-36), (Reyes, 2018, 295-307)

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