What can Hand Movements Tell us about Audience Engagement?

Lida Theodorou (l.theodorou@qmul.ac.uk)
School of Electronic Engineering and Computer Science, Mile End Road
London, E1 4NS

Patrick Healey (p.healey@qmul.ac.uk)
School of Electronic Engineering and Computer Science, Mile End Road
London, E1 4NS

Abstract

Conventional seated audiences have relatively restricted opportunities for response. Perhaps the most salient is applause but they use their hands to make other visible movements: to fix hair, adjust glasses, scratch ears. The question we address here is whether these apparently incidental movements may provide systematic clues about an audience's level of engagement with a performance. We investigate this in the context of contemporary dance performances by analysing audience hand movements in four performances at the London Contemporary Dance School. Hand movements were tracked using a reflective wristband worn by each audience member. A blob detection algorithm applied to the video recording examined whether changes in hand movement are associated with audience arousal levels to the performance. The results show that hands move least during the most preferred and most during the least preferred dance pieces. We conclude that still hands are a signal of higher levels of engagement.

Keywords: Audience; Engagement; Blob Detection; Hand movement; Handedness; Contemporary Dance.

Introduction: Interacting with Audiences

In many live performances audiences are separated from performers; seated in the dark observing the performance. The primary conventional opportunity for members of an audience to express their satisfaction or dissatisfaction about a performance is through applause and/or cheering. Nonetheless, audiences have notoriously recruited other means of signalling their ongoing responses including the organised and carefully timed use of apparently innocent activities such as coughing (Wagener, 2012; Broth, 2011).

Our programmatic hypothesis is that audiences' ongoing responses are part of a bi-directional system of audience-performer communication that distinguishes live from recorded performance. A key motivation for this hypothesis is that performers themselves distinguish between "good" or "bad" audiences for the same performance and between moments of engagement or "lift" and moments of boredom in an audience (Healey, Oxley, Schober, & Welton, 2009). The question this raises is what could performers be detecting in these situations that informs their dynamic sense of how well a performance is going. Here, we consider an especially restrictive case: contemporary dance. In a typical performance the audience will be in the dark, the performers behind bright lights and loud music accompanying the dancing. Audience behaviours are restricted by conventions on the types of response that it is considered acceptable to display. Performers are constrained by the need to concentrate on the physical movements required for their performance. In contrast to live genres such as Street Performance, Stand-up Comedy or Drama there few, if any, opportunities for direct eye contact or verbal exchanges with the audience. Almost the only available channel of communication between audience and performers is body movements.

One overt physical response that is visually salient and potentially detectable by dancers is audience hand movements. Casual observation of a dance audience reveals a wide range of ongoing hand-movements by audience members involving an apparently diverse set of activities: scratching, adjusting hair, adjusting glasses, support the chin and drinking amongst others. The question addressed here is whether these movements may provide a signal of audience engagement and thereby form part of a feedback cycle between the performers and their audience.

Measuring Audience Responses

Understanding and sensing audience responses can provide an evaluation tool to help performance directors understand how their work is received. Performance unfolds in time, making the collection of data more problematic for researchers (Schubert, Vincs, & Stevens, 2009). However, there are a growing number of studies in dance research that use sensing technologies to examine dancer positions in time (Calvo-Merino, Glaser, Grèzes, Passingham, & Haggard, 2005) although very little research has focused specifically on audiences (Katevas, Healey, & Harris, 2015; Gardair, Healey, & Welton, 2011; Vincs, Stevens, & Schubert, 2010; Healey et al., 2009).

The most obvious way that one can measure satisfaction in audiences is from the levels of applause. Mann, Faria, Sumpter, and Krause (2013) used a mathematical model to quantify the role of social contagion in the starting and stopping of applause during a presentation. They found that the rate at which new individuals start clapping is proportional to how many people are already clapping. However, this is a measure of response after the end of the presentation rather than a concurrent response. An alternative approach asks participants to make explicit self-reports of their responses during a performance. Vincs et al. (2010) took this approach with a 'portable Audience Response Facility' (pARF), a PDA that records participant's ratings of engagement during a dance work. They found that periods of high self-reported engagement often follow choreographic surprises, and that periods of low engagement tend to be associated with more predictable dance structures (Vincs et al., 2010; Vincs, Schubert, & Stevens, 2009). Using a post-performance methodology, Stevens et al. (2009), explored the reactions of 472 audience members as they watched contemporary dance by using an Audience Response Tool (ART) that collects responses using qualitative and quantitative questionnaires. Some of the items probed participants on their experience and enjoyment of the performance included visual and aural cues, dancer characteristics, movement, choreography, novelty, spatial elements, intellectual and emotional stimulation. Unfortunately, the act of asking participants to evaluate the performance after its end has the disadvantage of the "peak-end" effect, which shows that a measure taken immediately after an experience is strongly influenced by the peak emotion and by the emotion experienced at the end of the experience.

Two non-intrusive approaches have demonstrated connections between the movements of performers and audiences as an element of live feedback between performers and audience. Healey et al. (2009) pioneered the use of motion capture techniques in this context by exploring the intercorrelations between patterns of head movement between a seminar speaker and their audience during a seminar. The results of their study indicate that head movements of the performer are reliably triggered by head movement of audience members. Using a detailed ethnographic approach, Gardair et al. (2011) examined audience dynamics in a study of street performance in Covent Garden. She explored how passers-by notice when a street performance is happening, by first becoming watchers and then transformed into audience members. Gardair argued that people's body orientations show the spaces that people most often interact and also that people use their body torque to express their engagement levels with the performance.

What Do Hand Movements Signal?

Although hand movements are visually salient they have a wide variety of potential causes. It is especially challenging to interpret naturally occurring audience hand behaviour without convergent verbal feedback. Most of the gesture literature focuses on explicitly designed co-speech gestures. Audience hand behaviour includes hand to face gestures or self-touch gestures (STG) that appear to lack overt, intentional design and may be performed with little or no awareness (Harrigan, Kues, Steffen, & Rosenthal, 1987). One important class of non-speech hand movements that are relevant for audiences are self-touch gestures (STG's). According to Harrigan et al. (1987), 55% of STG are applied to head or face, 8% are applied to the legs and 2% of STG are directed to the trunk. They are thus likely to be visible at a distance.

Studies have shown that there is an increase in self-touching behaviour in stressful and fearful situations (Butzen, Bissonnette, & McBrayer, 2005; Heaven & McBrayer, 2000) although Ekman and Friesen (1972) suggested that STGs may also occur when a person is relaxed. Butzen et al. (2005) found a significant increase of STG in response to a video about chiggers compared to another kind of video. In a study from Heaven and McBrayer (2000) the participants listened to texts about leeches and canaries and then had to answer several questions. Although there were no differences between the two listening conditions there was an increase in STG for the leeches text during the answering period. Rogels, Roelen, and Van Meen (1990) found that children between 3 and 6 years showed more self-touch gestures while talking about a cartoon they had just seen than while watching the cartoon. Other studies (Grunwald, Weiss, Mueller, & Rall, 2014) hypothesise that there is a relationship between the frequency of STG and arousal. Barroso and Feld (1986) investigated this by testing the occurrence of self-touch gestures performed with one or both hands as a function of four different auditory attention tasks. They found that with increasing complexity and attentional demands both one and two handed self-touch gestures increased. Handedness also appears to play a role. Kimura (1972) showed right handed participants perform STG's equally often with the left and the right hand. However, there is evidence that people use their right and left hand for different reasons while talking. Kipp and Martin (2009) found an association of handedness with the emotional dimensions of arousal. In particular, they found that the right hand is used more when experiencing anger and the left hand when experiencing relaxed and positive feelings. According to Roether, Omlor, and Giese (2010) the body seems asymmetric in its emotional expressivity. The left side uses higher energy and higher amplitude for emotional movements than the right side.

Hand behaviour and boredom is another relationship that might help us interpret audience hand movements. According to Kroes (2005) people experiencing boredom tend to relax their body muscles. Bull (1978) claims that there are specific head positions that characterise boredom such as drops head, turns head and head lean. Bored people also tend to use their hands to support their head or perform self-touching gestures (rubbing or clutching face). However, Kroes (Kroes, 2005) notes that this hand behaviour is a sign of low arousal but it might not be a sign of dissatisfaction. According to Bianchi-Berthouze, Kim, and Patel (2007), boredom is mostly associated with the decrease of body movement. However, contradictory findings show that increase of movement was associated with frustration, loss of interest and boredom (Kapoor, Burleson, & Picard, 2007), this suggests that boredom can also correlate with episodes of high movement. In summary, we believe that the claims in the literature about movements and boredom are not entirely consistent and seem to depend a lot on the social context of the activity.

Overall, the interpretation of hand gestures is problematic however, it appears that STG are implicated in the regulation of emotional and cognitive processes. Based on the literature presented above we believe that in the context of contemporary dance audience hand movement might give us information about audience engagement to the performance. We try to investigate this by first testing the general hand behaviour patterns that evoke in an audience and then examine whether these patterns affect the audience engagement. This paper presents some initial results relevant to audience hand motion patterns by testing the following hypotheses. The first two hypotheses examine whether hands are an important sign of audience engagement that might be detectable by the dancers.

Hypothesis 1 (H1): *Audience hand movements provide a potentially salient signal of response to performers.*

Hypothesis 2 (H2): *If hand movements have a special status as a response signal they should diverge from other movements.*

In addition, hypothesis 3 and 4 examine the relationship of hand speed with engagement and/or boredom. In contrast to the association of boredom with low movement described above, we believe that in the context of a dance performance applies the opposite. Based on this we will test the following hypotheses:

Hypothesis 3 (H3): *Less movement of hands on face signals engagement.*

Hypothesis 4 (H4): *More movement of hands on face signals disengagement.*

These hypotheses will be tested using the methodology described below.

Performances by London Contemporary Dance School

The study presented in this paper took place at "ThePlace" theater in London where four contemporary dance pieces performed by dancers of the London Contemporary Dance School(LCD). As part of our second study on audience responses, we filmed audiences and dancers during the performance. The performance lasted for 1 hour and 40 minutes and consisted of 4, 20 minute dance pieces (part 1 to part 4) and a 20 minute interval between the second and the third piece (see figure 1). Each dance was performed by LCD postgraduate students and directed by commissioned professional choreographers.

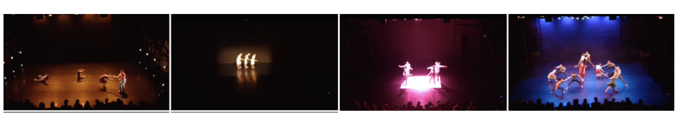

Figure 1: Performances Part 1 to Part 4 (from left to right) performed by LCD.

Methods

Equipment set-up

In order to be able to capture a big enough sample of the audience, we used two Basler ace (1280x1024px resolution) night vision cameras. An infrared light (IR) was attached on top of each camera so as to be able to film the audience during the dark periods of the performance. Both cameras and IR lights were placed on the theatre truss on top of the stage pointing towards the part of the audience to be filmed (See figure 2). For the filming of the dancers a JVC professional camera was hanged from the rig facing the stage. For a synchronised double GEV camera recording we used Gecko software made by Vision Experts operated on a Windows 10 pc. Gecko gave us more data accuracy since it provides a timestamp on each frame and is able to capture 45 frames per second.

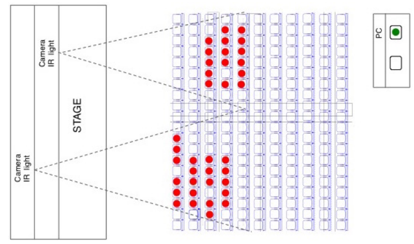

Figure 2: Plan drawing of "ThePlace's" theatre showing equipment setup.

Hand tracking: Reflective Wristbands

Apart from filming the audience and the dancers, the methodological aim of this study was to extract the hand (wrist) movements of each audience member automatically. In order to do this, we created bracelets made of 5mm reflective rope. A small plastic bag with two reflective bracelets together with instructions of how to wear them was placed on the arm of each theatre seat (See figure 3). Each audience member had to wear one wristband on each hand. The bracelets were only visible in the video recordings because of the IR lights shooting directly on them. This was the cheapest and easiest solution we could find to do an automatic tracking and record continuous wrist movements.

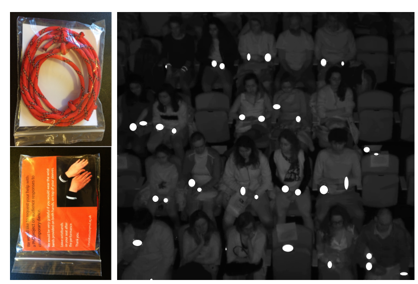

Figure 3: Front and back side of ziplock plastic bag with two reflective wristbands and how to wear instructions (left). Blob detection algorithm running on audience footage (right).

Hand and body data extraction

A blob detection algorithm made by the blobscanner processing library was applied on audience footage to track the reflective wristbands on each frame (See right image on figure 3). Blob detection is a computer vision method that is able to detect similar regions in a digital image, such as those with the same brightness or colour, compared to surrounding regions. In our case a blob is a region of white pixels (reflective wristbands) in the image. By applying this method on the videos, we extracted the position x,y of each blob in the image or in other words the right and left wrist locations of each audience member in each frame of the performance.

However, due to the complexity of the human hand movement and the limitations of the algorithm it was impossible to get a stable continuous detection of the hands since the algorithm was unable to attach and keep the correct blob on each hand throughout the frames. Due to this limitation, the data was extracted first, the hand positions x,y were played back on top of the footage and some manual work was done to help the algorithm pinpoint the correct blob for each hand for the whole duration of the video. By doing this we ended up with a datafile with the x,y positions of left and right hand of each audience member during each dance piece. In order to be able to test the significance of the hands in the performance, we compare their behaviour with that of the rest of the body. To measure the general upper-body movement of the audience, we used an optical flow algorithm. In particular we applied the algorithm on each person separately removing the optical flow vectors of each person's hands. This gave us the upper-body movement of each person without the movement of the hands (See images on figure 4).

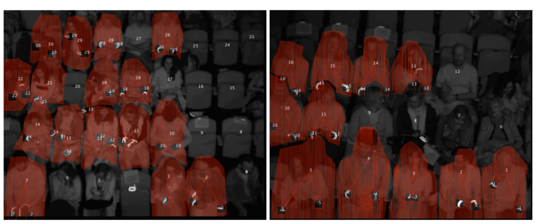

Figure 4: Captured areas for optical flow.

Results

The informal observation of the video footage showed that there were very few overt responses in the audience; the most salient identifiable movements were those of bringing the hands up to the face. Overall, we extracted hand motion data from 27 audience members (18 females and 9 males). In order to test if audience hands produce enough movement to be detectable by the dancers (H1), we measure the duration of hands being up and down as well as the hand speed during the performance. The results indicate that people have their hands on their faces for about half of the performance (42% of the time have their hands up compared to 58% that they have them down) while the hands are moving faster when they are up compared to when they are down, in a resting position. We examine separately the case of hands to the face by calculating the number of times each hand is moving (fix hair, adjust glasses, scratch ears) or not (hands on chin or supporting head). We found that overall the number of times the hands are moving is approximately the same with the times the hands are still (48% moving, 52% still). Therefore, it appears that the audience performs enough hand movements for the performers to detect. In order to examine if hand movement could provide us signals of audience affective state (H2), we compare its similarity to the movement of the upper-body. Figure 5 shows audience body movement and hand movement for each part averaged every 1 minute. From these two graphs, it is apparent that body and hands behave differently throughout the performance while overall there is a decrease of movement from part 1 to part 3 followed by a sharp increase in the movement of the hands at the end of part 4. From these two plots, it is apparent that audience body movement is low in part 2 compared to the other 3 parts while hand movement seems to be lowest in part 3. In summary, these findings provide us with some evidence that hand movement might be a significant audience response that might be detectable by the performers and can potentially give us information regarding audience engagement to the performance.

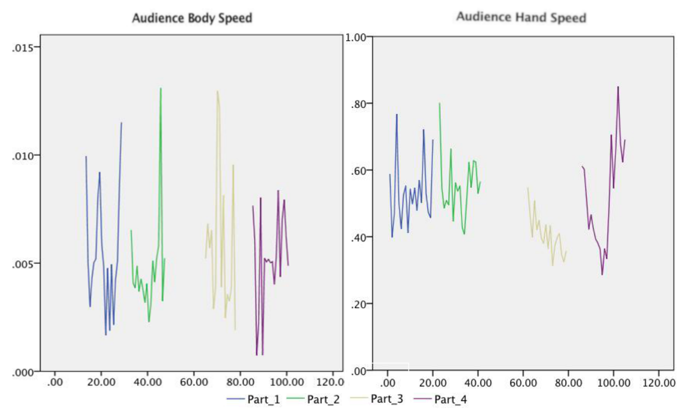

Figure 5: Upper-body speed (left) and hand speed (right) for each part of the performance averaged every 1 minute.

Focusing separately on each part of the performance, we next examine audience engagement levels by testing how long people keep their hands up or down and how do hands behave when they are up to the face (H3, H4). The left plot on figure 6 shows the amount of time hands are up or down in each part. It is apparent that people keep their hands on their face for longer as the performance progresses from part 1 to part 3, although that duration decreases slightly in part 4. The right plot on figure 6 shows the number of times hands are up (moving/not moving) for each part of the performance. From this plot, it appears that the mobility of the hands decreases as the performance progresses. Looking at the two plots, we see differences between the 4 parts of the performance. In part 1, hands seem to be down for longer while when they are up their mobility is relatively high. Overall, part 1 presents more moving than still hands. In part 3, people have their hands up for longer, however most of the time hands are still when they are up. This means that in part 3 we have an increase in the number of still hands on face. Finally, parts 2 and 4 are somewhere in between with the only difference that in part 2 hands are more likely to be found down while the opposite is true for part 4. In summary, it seems that there is an increase in the number of hands being on face while hands are getting stiller as the performance progresses. This result fits with the movement of the body that also decreases from part 1 to part 3. At the end of part 4 both body and hand speed increase. We compared these results with audience preference levels for each part through an online survey sent to participants with a range of familiarities to dance. The main aim of the survey was to ask people to watch the footage of the 4 dance pieces and rank them in order of preference. The order of the performances was randomised for each participant. We collected answers from 21 people (18 females and 3 males), 8 of which were professionally connected to dance and were watching dance more that 4 times a year. The rest were dance enthusiasts that were going to dance performances 3 to 4 times a year. The results of the survey indicate that the 2nd part of the performance is the most preferred, 3rd part comes next while 1st and 4th are the least preferred in that order. In comparison to the previously mentioned results, we observe that during the most preferred parts (part 2,3) there are more hands still on face while in the least preferred there is a higher mobility of the hands that gets more distinct at the second half of part 4, very end of the performance.

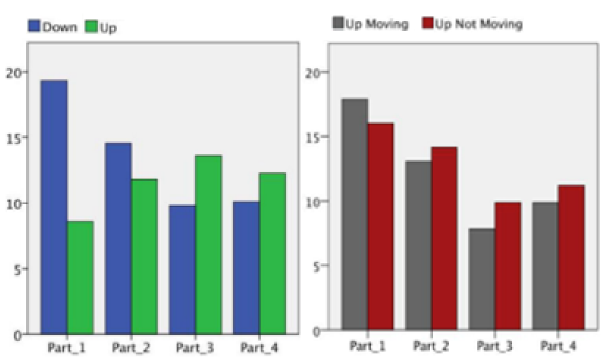

Figure 6: Duration of hands being up and down for each part of the performance (left). Number of time hands are up (Moving and Not moving) for each part of the performance (right).

An unexpected finding of this study is the different behaviour between audiences left and right hand. Overall, during the performance the left hand moves slightly faster than the right while the right hand is more likely to be found up on the face compared to the left. The first plot on figure 7 shows the mean speed of the left and right hand for each part of the performance. In parts 1 and 2 the left hand seems to move faster compare to the right while in the Part 3 and 4 is the other way around, the speed of the right hand is slightly higher compared to the left. Finally, the second plot on figure 7 shows the average number of times left and the right hand were found up for each part of the performance. This plot indicates that there is a difference between the number of times people use their left and right hand which is getting progressively bigger from part 1 to part 4.

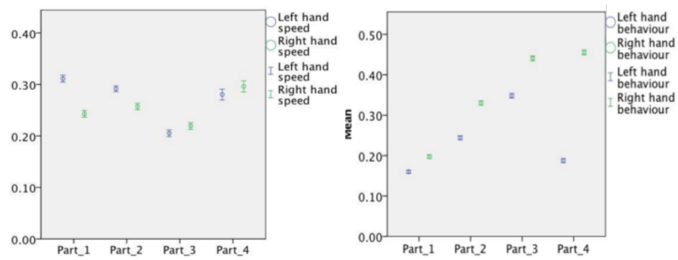

Figure 7: Mean hand speed of left and right hand for each part of the performance (left). Mean number of times left and right hand were up during each part (right).

Discussion

The results described above provide us with some initial clues to the importance of overt audience reactions to contemporary dance. Like Theodorou, Healey, and Smeraldi (2016), these results show that overall, audiences have their hands up to their faces for about half the performance while the speed of hand movements varies a lot throughout. This suggests that there is audience hand movements that are both frequent and potentially detectable to the dancers. Previous studies have shown that audience faces tend to be expressionless during dance performances and so hands might be the part of the body provide signals of satisfaction or dissatisfaction (Theodorou et al., 2016). Combined with the preferences expressed in the survey, the results show that the most preferred performances are the ones that the audience moves least while during the least preferred performances hand movement increases and people perform more self-touching gestures. We interpret this finding as suggesting that people become restless and this leads to more spontaneous self-touching gestures. These observations suggest that it is actually the lack of movement that is a key signal of how engaged people are in the performance and fidgeting and spontaneous self-touching relate more to audiences boredom or nervousness (Healey, Theodorou, & Woods, Forthcoming 2017). However, the ratings collected by the online survey can only capture overall preference levels, rather than the momentary engagement of the audience. This is something that needs to be explored in future work by, for example, showing people shorter videos from different parts of a performance instead of judging the dance piece as a whole.

An unexpected finding of the study was the systematically different behaviour of the left and right hand throughout the performance. In particular, the results indicate that overall the left hand moves faster compared to the right while the right hand is more likely to be found up. This finding is opposite to what we found in our first study which showed that people have their left hand up more times and for longer compared to the right hand. These different hand responses may indicate that people have a left-right asymmetry in their expressiveness when watching dance. Kipp and Martin (2009) have proposed that there is an association of gesture handedness with the emotional dimensions of pleasure and arousal. In the future we plan to examine this association further, and test the aforementioned questions of boredom and engagement using a more controlled methodology with recruited audience members.

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References

Barroso, F., & Feld, J. K. (1986). Self-touching and attentional processes: The role of task difficulty, selection stage, and sex differences. *Journal of Nonverbal Behavior*, *10*(1), 51–64.

Bianchi-Berthouze, N., Kim, W. W., & Patel, D. (2007). Does body movement engage you more in digital game play? and why? In *International conference on affective computing and intelligent interaction* (pp. 102–113).

Broth, M. (2011, June). The Theatre Performance as Interaction between Actors and Their Audience. *Nottingham French Studies*, *50*(2), 113–133.

Bull, P. (1978). The interpretation of posture through an alternative methodology to role play. *British Journal of Clinical Psychology*, *17*(1), 1–6.

Butzen, N. D., Bissonnette, V., & McBrayer, D. (2005). Effects of modeling and topic stimulus on self-referent touching. *Perceptual and motor skills*, 413–420.

Calvo-Merino, B., Glaser, D. E., Grèzes, J., Passingham, R. E., & Haggard, P. (2005, August). Action observation and acquired motor skills: an FMRI study with expert dancers. *Cerebral cortex (New York, N.Y. : 1991)*, *15*(8), 1243–9.

Ekman, P., & Friesen, W. (1972). Hand Movements. *Journal of Communication*.

Gardair, C., Healey, P. G., & Welton, M. (2011). Performing places. *Proceedings of the 8th ACM conference on Creativity and cognition - C&C '11*, 51.

Grunwald, M., Weiss, T., Mueller, S., & Rall, L. (2014, April). EEG changes caused by spontaneous facial self-touch may represent emotion regulating processes and working memory maintenance. *Brain research*, *1557*, 111–26.

Harrigan, J. a., Kues, J. R., Steffen, J. J., & Rosenthal, R. (1987, December). Self-Touching and Impressions of Others. *Personality and Social Psychology Bulletin*, *13*(4), 497–512.

Healey, P. G. T., Oxley, R., Schober, M., & Welton, M. (2009). Engaging Audiences. , 1–2.

Healey, P. G. T., Theodorou, L., & Woods, P. (Forthcoming 2017). *Stillness and motion: Two hypotheses about audience engagement.*

Heaven, L., & McBrayer, D. (2000). External motivators of self-touching behavior. *Perceptual and motor skills*(1981), 338–342.

Kapoor, A., Burleson, W., & Picard, R. W. (2007). Automatic prediction of frustration. *Int. J. Human-Computer Studies*, *65*, 724–736.

Katevas, K., Healey, P. G. T., & Harris, M. T. (2015, August). Robot Comedy Lab: experimenting with the social dynamics of live performance. *Frontiers in Psychology*, *6*(August), 1–9.

Kimura, D. (1972). Manual activity during speaking - 1. Right-handers*. *Neuropsychologia*, 45–50.

Kipp, M., & Martin, J.-C. (2009, September). Gesture and emotion: Can basic gestural form features discriminate emotions? *2009 3rd International Conference on Affective Computing and Intelligent Interaction and Workshops*, 1–8.

Kroes, S. (2005). Detecting boredom in meetings. *University of Twente*, 1–5.

Mann, R. P., Faria, J., Sumpter, D. J. T., & Krause, J. (2013). The dynamics of audience applause The dynamics of audience applause. (June).

Roether, C. L., Omlor, L., & Giese, M. A. (2010). Dynamics of Visual Motion Processing. , 313–340.

Rogels, P. L. J. M., Roelen, E., & Van Meen, J. (1990). The function of self-touchings, posture shifts, and motor discharges in children from 3 to 6 years of age. *Perceptual and motor skills*, 1169–1178.

Schubert, E., Vincs, K., & Stevens, C. (2009). A Quantitative Approach to Analysing Reliability of Engagement Responses to Dance.

Stevens, C. J., Schubert, E., Morris, R. H., Frear, M., Chen, J., Healey, S., ... Hansen, S. (2009, September). Cognition and the temporal arts: Investigating audience response to dance using PDAs that record continuous data during live performance. *International Journal of Human-Computer Studies*, *67*(9), 800–813.

Theodorou, L., Healey, P. G., & Smeraldi, F. (2016). Exploring audience behaviour during contemporary dance performances. In *Proceedings of the 3rd international symposium on movement and computing* (p. 7).

Vincs, K., Schubert, E., & Stevens, C. (2009). Measuring Responses to Dance. *Dance Dialogues: Conversations across cultures, artforms and practices*.

Vincs, K., Stevens, C., & Schubert, E. (2010). Effects of observer experience on continuous measures of engagement with a contemporary dance work. *Proceedings of the 9th Conference of the Australasian Society for Cognitive Science*, 357–361.

Wagener, A. (2012). Why do people (not) cough in concerts? The economics of concert etiquette.