Connecting on Movie Night? Neural Measures of Engagement Differ by Gender

Samuel B. Barnett, Northwestern University, USA
Moran Cerf, Northwestern University, USA

ABSTRACT

We propose a novel method, Cross Brain Correlation (CBC), to study between-group differences in responses to complex stimuli, such as movies or advertisements, based on agreement across multiple brains while experiencing content. Clustering this neural data (i.e. segmentation by gender) can distill preferences that are not captured by traditional means.

INTRODUCTION

The ability to generate engaging content is a sought-after skill, especially when the goal is to simultaneously connect with multiple consumer segments (e.g., various interests, ages, genders). Be it in advertising, architecture, cinematography, gaming, politics, product design, or any other field in which content is being delivered to an audience, the ability to capture the interest of different groups, such as men and women, is regarded as a talent that is both hard to obtain and hard to dissect. Prior research on content engagement has explored a variety of techniques, including repetition (Campbell and Keller 2003), endorsements by popular figures (Choi et al. 2013), testimonials (Albuquerque 2012), and others. However, these methods are often inefficient and expensive (Swerdlow 1984). Recently, neuroscientists have broadly linked engagement to attention (Koster et al. 2006), decreased mind-wandering (Mason et al. 2007), and increased memory of displayed content (Olivers et al. 2006; Furman et al. 2007). Prior studies have specifically tried to locate a set of brain regions uniquely activated when subjects are engaged by content (Yamasaki et al. 2002). While a body of literature has offered some evidence of regional networks that indicate momentary shifts in attention (Mason et al. 2007, Esterman et al. 2012), neuroscientists have yet to identify a clear, finite set of brain regions whose activity correlates with engagement as a whole within an individual.

One characteristic of engaging content is its ability to transcend differences in individual preferences and generate widespread interest. When an entire audience is particularly captivated, there are observable behavioral similarities across members of the crowd: sitting on the edge of seats, looking in the same direction, laughing at the same time, etc. In recent works by Hasson et al. (Hasson et al. 2004, Furman et al. 2007, Regev et al. 2013), the brains of viewers of short videos show increased Inter-Subject Correlation (ISC) for clips that are deemed to be more engaging by the authors. Borrowing from this intuition that engaging content triggers similar responses across people, we have developed a complementary way to study neural data by looking at the correlation between multiple brains, rather than the activity or lack thereof within a single brain (or brain regions). Additionally, we interrogate the dynamic nature of this correlation (i.e., changes from moment to moment) rather than focusing only on the average throughout the stimulus.

Neural synchrony within individual brains has been studied extensively with the aim of understanding epileptic seizures, which are characterized by abnormal patterns of synchronization within an individual's brain (Cerf and Barnett 2014). Now, we apply the concept of neural synchrony across individuals as a way to interpret the effect of different audiovisual content on viewers.

Our new measure, Cross-Brain-Correlation (CBC), inspired by measures of neural similarity between brains presented in previous works (Hasson et al. 2004, Furman et al. 2007, Regev et al. 2013), enables researchers to make temporally precise conclusions about presented content and allows for algorithmic or manual clustering of the neural data to study specific segments of the population. Importantly, by directly measuring neural responses, this measure does not depend on conscious, subjective reporting, which is often distorted by situational or idiosyncratic biases (Oppenheimer et al. 2009). Additionally, previous studies have utilized functional Magnetic Resonance Imaging (fMRI) in a laboratory setting. To test the generalizability of our approach outside the laboratory and use a more cost-effective and portable technology than fMRI (thus, more accessible for businesses), we performed our experiment using another neural measurement technology—electroencephalography (EEG)—in a more natural setting (commercial movie theater).

This new analytical paradigm for assessing audience reactions first measures the neural activity induced by the content in an individual brain, and then calculates its similarity to that of other brains processing the same content (details in Methods section). While brains might have lower activity in certain regions and higher in others at a given moment, this collective pattern could in fact be indicative of the effect of external content if it is influencing multiple brains in the same fashion.

Notably, while CBC captures the overall agreement across multiple brains, certain subgroups of individuals may be experiencing content in alternative ways. Rather than grouping all subjects together for the CBC computation, which may wash out effects of divergent subpopulations, we now ask whether clustering subjects (e.g., segmentation by gender and interests) and then measuring the corresponding CBCs can lead to greater understanding of these groups. We seek to address this question using a behavioral study (Study 1) and an EEG field experiment (Study 2). The execution of Study 2 further shows that CBC can be practically implemented under natural conditions (e.g., in a commercial movie theater), suggesting the technique could be used in industry (e.g., to identify differential engagement across gender lines for the purposes of targeted advertising or entertainment). In this work, the subsets of interest are male and female viewers, and we use CBC to identify moment-to-moment differences between their responses to the same audiovisual content.

METHODS

Study 1: Behavioral Research

Subjects and Procedure. Sixty-four subjects (43 female, 21 male) watched advertisements and movies at a commercial theater, through our partnership with AMC Entertainment Holdings, Inc. (NYSE: AMC). Subjects selected a movie of their choice that they had not previously seen from a list of the theater's regular showtimes, and they were given free admission in exchange for participation in a survey immediately following the movie. All subjects were native English speakers with normal hearing who provided informed consent.

Free Recall and Survey Data. As subjects exited the auditorium, they were asked to participate in a survey. First, subjects were asked to recount the plot of the movie in detail. Second, they were asked to write the title and plot for each trailer that they remembered. For each trailer, they were asked to what extent they enjoyed the content on a scale of one to ten. Subjects were then asked about their general movie preferences (e.g., favorite genre), factors that influence their movie selection (e.g., user reviews, scores, recommendation from friends, spontaneous decision at theater, viewing trailers), movie theater attendance rates, and demographic characteristics. They were also asked to recall the plot of an advertisement (Coca-Cola) and the plot of the theater's policy announcement (asking moviegoers to turn off cell phone). These stimuli were selected because they are shown to every moviegoer at the theater regardless of movie selection (as opposed to the trailers, which vary based on the selected movie's genre, Motion Picture Association of America rating, production studio, etc.).

Study 2: EEG Field Experiment

Subjects and Procedure. Fifty subjects (24 female, 26 male) distinct from Study 1 watched trailers and movies at a commercial theater, as in Study 1, except that these subjects were also undergoing EEG recordings. Subjects were also offered free soft drinks and popcorn, but were not allowed to consume these concessions while undergoing the EEG recordings to avoid interfering with the neural measurements. Subjects were fitted with an electrode cap with a circumference of either 54cm or 58cm depending on head size and comfort with the cap's tightness. While the subjects were wearing the caps, a washable conductive gel was placed with a syringe at each electrode site on the subjects' scalps. For each showtime in our study (n = 44), we collected data from multiple subjects seated next to each other at a preferred row dedicated for the study. All subjects were native English speakers with normal hearing who provided informed consent. Additionally, we explained the experiment to other moviegoers and theater staff (not participants) in the vicinity to avoid interruptions.

EEG Data Acquisition. Subjects' neural data were collected using a 32-channel EEG system (Brain Products GmbH, Gilching, Germany) at a rate of 250 samples per second. Each electrode connection was verified to be functioning properly (i.e., detecting electrical activity from the scalp) before starting the recording. In the rare event that the function of certain electrodes was interrupted or discontinued during the recording, the electrical activity at that site could be calculated as a weighted average of signals from nearby functioning electrodes.

Free Recall and Survey Data. Upon completion of the movie, subjects were asked to participate in a survey while they continued to be monitored using the EEG system. In the interest of time (since theater staff needed to clean the auditorium in between showtimes), we asked a subset of the questions posed in Study 1. We always asked the core recall questions regarding the plot of the movie and the title and plot of each trailer. Additionally, we always asked subjects to rank the four major genres (action, comedy, drama, horror), how they decided which movies to watch, how often they visited the movie theater, and demographic characteristics.

CBC. We measured moment-to-moment synchrony across subjects experiencing the same audiovisual stimuli, which we deem Cross-Brain-Correlation (CBC). We measured EEG activity over time as the power (dB) of statistically significant spectra in the following way: for each electrode channel, we performed a Short-Time Fourier Transform (STFT) at each timestep, filtered the resulting Power Spectral Density (PSD) matrix, and multiplied the common logarithm (base 10) of the matrix by 10; we then averaged across the 32 electrode channels to produce a single time series of EEG activity. The 32 electrode positions were distributed across the entire scalp according to the actiCAP 64Ch Standard-2 montage (green holders). Finally, we compute the correlation of the EEG activity between all pairs of subjects (or all pair of subjects in a particular subset, e.g., all female subjects, all male subjects, all subjects who prefer action movies) to arrive at a CBC time series.

RESULTS

In Study 1 (Behavioral Research), we assessed the degree to which subjects could recall trailers for upcoming movies. In general, the theater presents six or seven trailers before each movie, yet subjects on average can only recall 2.6 ± 1.5 trailers. Only 13 out of the 64 subjects could recall more than half of the trailers they viewed. The apparent difficulty of this task was observed independent of the gender of the subjects: female subjects recalled 2.6 ± 1.3 trailers and male subjects recalled 2.5 ± 1.8 trailers (not significantly different, two-tailed t-test, $p = .82$). Also, the median number of recalled trailers for both female and male subjects was three.

We also investigated the recall of specific events in an advertisement for Coca-Cola that was presented in every showtime after the sequence of trailers and before the featured movie itself. On average, subjects recalled slightly more than one event from the 30-second video. While most events throughout the advertisement generated similar levels of recall for male and female viewers, there were several notable exceptions. For example, the advertisement begins with the Coca-Cola cup appearing in the distance ($t = 1$s, see Summary Table); 14% of female subjects reported this event, but no male subjects did so. The climax of the advertisement is when an animated character dramatically inserts a straw into the Coca-Cola cup ($t = 19$s, see Figure 1 and Summary Table); 38% of male subjects recalled this event—more than any other moment in the video—compared to only 28% of female subjects. This moment includes masculine imagery of the protagonist wielding the straw like a weapon. Therefore, we expected the neural responses of male and female viewers to diverge at these times.

In Study 2 (EEG Field Experiment), we first sought to predict trailer recall from the neural data. Throughout our experiment, there were 13 movie trailers that were shown in more than one showtime and subsequently recalled by more than one subject. We computed the average CBC throughout each of the trailers to compare with the corresponding level of recall. We found that average CBC was highly correlated with trailer recall ($r = .66$, $p = .01$). This finding suggests that CBC not only demonstrates differences in neural perception, but actually predicts memorability of content. Importantly, CBC can be retrieved without the need to ask the subjects and is therefore invariant to the subjectively perceived experience.

Next, we asked whether clustering the neural data based on demographic information could highlight meaningful similarities and differences in reactions across groups. As an example, we partitioned the neural similarity data according to gender and identified key moments in the advertisement where the groups converged or diverged (see Figure 1 and Summary Table). Suggesting labels for such moments can potentially enable the design of targeted messages that generate more engagement in a specific group (e.g., one particular gender).

As we expected, the appearance of the Coca-Cola cup ($t = 1$s, see Summary Table)—which was exclusively recalled by female subjects—generated higher CBC in female subjects (.42) than male subjects (.22). Furthermore, the climactic straw insertion ($t = 19$s, see Figure 1 and Summary Table)—which male subjects recalled more often than female subjects—produced the most striking divergence between each gender's CBC. The maximum CBC observed for male pairs (normalized to 1) occurred at this moment, which was significantly higher (one-tailed t-test, $p < .01$) than the corresponding CBC for female pairs (.16) (see Figure 1 and Summary Table).

There were also numerous examples of content that highly engaged both genders, such as the falling action (protagonist is airlifted away, $t = 21$s, see Summary Table) and conclusion (animated audience drinks Coca-Cola, $t = 27$s, see Figure 1 and Summary Table).

Neither of these moments have obvious gender-specific characteristics, while both are key elements of the overall plot of the advertisement, producing similar levels of recall in both genders (not significantly different, two-tailed t-test, $p = .59$) in Study 1. Altogether, these observations show various parallels and differences between male and female viewers in their neural responses to content, measured by the level of similarity across brains of the same gender during viewing.

Notably, many of the differences between male and female brains detected in Study 2 were not apparent in the survey and memory tasks in Study 1, suggesting that neural data can capture fine preferences that are not observable otherwise. CBC, tapping directly into neural signals, is thus able to shed light on moments in the content where male and female experiences differ, providing new insights to power content generation and targeted delivery for specific segments.

Finally, to evaluate the robustness of the measure, we tested whether we could use the neural data at a significant moment in the advertisement (e.g., straw inserted into cup, $t = 19$s) and successfully decipher characteristics of the subjects, such as gender and genre preference. Simply put, we wanted to see whether, in the absence of any a priori label knowledge of the subjects (e.g., gender, genre preference), we could parse their identities or preferences merely using the neural data at key moments in the viewing.

We found that a supervised machine learning approach applied to the neural data can accurately decode the genders of groups of subjects. Our algorithm computed all possible combinations of six male subjects and six female subjects (26 choose 6 male groups, 24 choose 6 female groups), and then computed the CBC for each of 500 randomly sampled groups for each gender. Finally, we used a binary classifier to successfully distinguish between male and female groups while varying its discrimination threshold; the area under the curve (AUC) of the resulting Receiver Operator Characteristic (ROC) was .76.

Given the apparent connotation of the straw as a weapon, we investigated whether moviegoers with different genre preferences (in particular, those who favor action movies, which are characterized by weapons and fight scenes) reacted differently to this moment. We repeated our machine learning approach using combinations of subjects that favored action movies (14 choose 6 groups), comedy movies (18 choose 6 groups), and drama movies (13 choose 6 groups). Subjects who reported preferring action movies to drama or comedy also had a particularly high CBC during this moment (straw inserted into cup, $t = 19$s). For ease of comparison with the other genre preference groups, we normalized the CBC of subjects preferring action to 1 and found much lower CBCs for subjects preferring drama (.31) or comedy (.21) at this instant. Using the aforementioned machine learning technique, we accurately identified which groups of subjects preferred action movies using their neural signals alone (AUC = .78).

In both of our machine learning analyses, the AUC (i.e., discrimination ability) was even larger with increased sizes of the sample groups. Additionally, the analyses performed are merely examples of distilling characteristics or preferences of subjects strictly via their neural activity. The underlying principle generalizes beyond the specific features (i.e., gender, genre preference), the selected moment (i.e., straw inserted into cup, $t = 19$s), and the stimulus (i.e., advertisement).

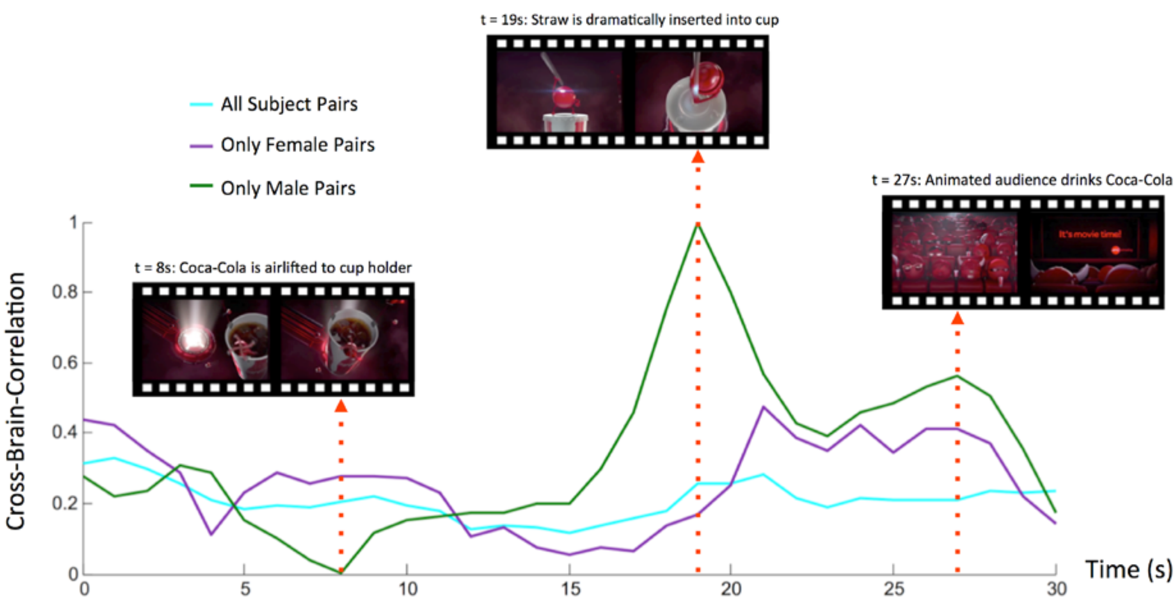

Figure 1: CBC Clustered by Gender. The green line depicts the CBC for male pairs only (normalized to range from 0 to 1 throughout the advertisement) and the purple and cyan lines represent the CBC for female pairs only and all pairs, respectively, on the same normalized scale. The dashed red arrows indicate three examples of moments in the advertisement during which male and female responses diverged.

Summary Table: CBC at Representative Samples of Advertisement. Data from five moments (selected to represent each component of the plot of the advertisement) are presented in the table. For this advertisement, both male and female CBCs achieve local maxima at the conclusion of the advertisement. However, male subjects responded maximally to the climactic moment whereas female subjects responded maximally to the rising and falling actions. For each gender, the Change Above Average was calculated as the percentage at which the CBC at that stimulus sample exceeded the mean CBC for that gender throughout the stimulus. The Gender Difference column shows the difference (numerically and graphically) in absolute CBC values between male subject pairs and female subject pairs.

Stimulus Sample		Cross-Brain-Correlation (CBC)		
Time (s)	**Description**	**Male Pairs (Absolute CBC)** (Change Above Average)	**Female Pairs (Absolute CBC)** (Change Above Average)	**Gender Difference (Absolute CBC)** (Graphic Representation)
1	Exposition	**0.22**	**0.42**	**-0.20**
		-48%	75%	♂ │ ♀
	Coca-Cola appears in distance	Local Minimum	No Extremum	Male < Female
8	Rising Action	**0.00**	**0.28**	**-0.28**
		-100%	15%	♂ │ ♀
	Coca-Cola is airlifted to cup holder	Absolute Minimum	Local Maximum	Male < Female
19	Climax	**1.00**	**0.16**	**0.84**
		138%	-33%	♂ │ ♀
	Character inserts straw into cup	Absolute Maximum	No Extremum	Male > Female
21	Falling Action	**0.58**	**0.48**	**0.10**
		38%	100%	♂ │ ♀
	Character is airlifted away	No Extremum	Absolute Maximum	Male > Female
27	Conclusion	**0.56**	**0.41**	**0.15**
		34%	71%	♂ │ ♀
	Animated audience drinks Coca-Cola	Local Maximum	Local Maximum	Male > Female

DISCUSSION

The clustering results suggest that partitioning the neural data, even in a basic way (e.g., along gender lines), can be valuable. Regions of similarity and dissimilarity between clusters can both provide more detailed insight into the target audience's mind. As expected, some content produces similar responses across gender lines, while other content has varied effects. From the collective neural responses to the advertisement (all subject pairs, cyan line in Figure 1), it is hard to identify any moment as significant, yet the data clustered by gender tells a much richer story. Additionally, while most of the aforementioned results relate to specific moments, comparing the entire time series as a whole can also enhance our understanding of the overall differences between male and female responses to the stimulus. For example, the variability of the CBC for male pairs only viewing the advertisement (SD = .23) was higher than that for all pairwise combinations (SD = .05) and for female pairs only (SD = .13), which suggests that male brains experienced a greater range of engagement level throughout the stimulus. Alongside existing methods utilizing other neural acquisition techniques, such as Inter-Subject Correlation (Hasson et al. 2004), these results offer convergent evidence that studying subjects' neural responses while they observe content can help distill the neural correlates of engagement. In particular, our findings suggest that gender-clustered CBC would be especially useful in neuromarketing to gain new insight into the potentially divergent minds of men and women.

A single brain can reveal so much about a person, but the study of multiple brains can add another dimension to our understanding. We have found that the time series of CBC (moment-to-moment similarity between brains) for each gender converge and diverge at certain moments in audiovisual content. In this work, we use segmentation by gender as an example application of our technique for studying between-group differences in responses to complex audiovisual stimuli. To illustrate this point, we have extended our analysis by partitioning the subjects by other parameters, such as age and surveyed genre preference. Notably, in testing for additional segmentation variables, we observed a similar time series for our youngest (<18 years old) and oldest (>55 years old) subjects viewing the advertisement, whereas these patterns differed from any of the intermediate age brackets (18-24, 25-34, and 35-55 years old). Additionally, subjects ranking the action genre as their favorite, compared to those who prefer drama or comedy, have considerably heightened CBC while viewing representations of weapons. Further work can explore other partitions of this data as well as responses to alternate stimuli. Since engagement inherently depends on connections between people, comparing neural activity across subjects seems to fit as a lens to view this complex area of research and can have direct implications for practitioners in marketing and other fields in which content and its effect on individuals is of importance.

REFERENCES

Albuquerque, Paulo, Polykarpos Pavidis, Udi Chatow, Kay-Yut Chen, Zainab Jamal (2012), "Evaluating Promotional Activities in an Online Two-Sided Market of User-Generated Content," *Marketing Science*, 31, 3 (May-June 2012).

Campbell, Margaret C. and Kevin Lane Keller (2003), "Brand Familiarity and Advertising Repetition Effects," *Journal of Consumer Research*, 30, 2.

Cerf, Moran and Samuel B. Barnett (2014), "Epilepsy — Eavesdropping on the Conversations of Rebellious Neurons," *Journal of Neurology and Neurophysiology*, 5:237.

Choi, Sejung Marina, Wei-Na Lee, Hee-Jung Kim, (2005), "Lessons from the Rich and Famous: A Cross-Cultural Comparison of Celebrity Endorsement in Advertising," *Journal of Advertising*, 34, 2 (2013-03-04), 85-98.

Esterman, Michael S., Yu-Chin Chiu, Leon Gmeindl, Steven Yantis (2012), "Tracking cognitive fluctuations with multivoxel pattern time course (MVPTC) analysis," *Neuropsychologia*, 50, 4 (March 2012), 479-486.

Furman, Orit, Nimrod Dorfman, Uri Hasson, Lila Davachi, Yadin Dudai (2007), "They saw a movie: Long-term memory for an extended audiovisual narrative," *Learning and Memory*, 14 457-467.

Hasson, Uri, Yuval Nir, Ifat Levy, Galit Fuhrmann, Rafael Malach (2004), "Intersubject Synchronization of Cortical Activity During Natural Vision," *Science*, 303, 5664 (2004-03-12), 1634-1640.

Koster, H.W., Geert Ernst Crombez, Bruno Verschuere, Stefaan Van Damme, Jan Roelf Wiersema (2006), "Components of attentional bias to threat in high trait anxiety: Facilitated engagement, impaired disengagement, and attentional avoidance," *Behaviour Research and Therapy*, 44, 12 (December 2006), 1757-1771.

Mason, Malia F., Michael I. Norton, John D. Van Horn, Daniel M. Wegner, Scott T. Grafton, C. Neil Macrae (2007), "Wandering Minds: The Default Network and Stimulus-Independent Thought," *Science*, 315, 5810 (2007-01-19), 393-395.

Olivers, N. L., Frank Meijer, Jan Theeuwes (2006), "Feature-based memory-driven attentional capture: Visual working memory content affects visual attention." *Journal of Experimental Psychology: Human Perception and Performance*, 32, 5 (October 2006), 1243-1256.

Oppenheimer, David M., Tom Meyvis, Nicolas Davidenko (2009), "Instructional manipulation checks: Detecting satisficing to increase statistical power," *Journal of Experimental Social Psychology*, 45, 4, (July 2009), 867-872

Regev, Mor, Christopher J. Honey, Erez Simony, Uri Hasson (2013), "Selective and Invariant Neural Responses to Spoken and Written Narratives," *Journal of Neuroscience*, 33, 40 (2013), 15978-15988.

Swerdlow, Robert A. (1984), "Star studded advertising: Is it worth the effort?" *Journal of the Academy of Marketing Science*, 12, 3 (Summer 1984), 89-102.

Yamasaki, Hiroshi, Kevin S. Labar, Gregory Mccarthy (2002), "Dissociable prefrontal brain systems for attention and emotion," *Proceedings of the National Academy of Sciences of the United States of America*, 99, 17 11447-11451.