WHITE PAPER

Second-by-second categorisation of brain states to measure the impact of TV commercials on consumers

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Contents

Executive Summary

K-Web (Kadence Window to the Eye and Brain) is a proprietary research solution, developed by independent market research agency Kadence International to evaluate the impact of TV commercials on consumers. K-Web uses electroencephalogram (EEG) to capture the intuitive responses of respondents' brains to stimulus seen and heard.

This research sought to take raw EEG data output from respondents and classify it into one of five brain states: 'Cognition', 'Confused', 'Partial Cognition', 'Detached' and 'Sleep' for every second of stimulus. The improvised K-Web methodology is scientifically robust at ascertaining distinct brain states, enabling us to combine respondents' unarticulated and intuitive brain responses to TV commercials with more traditional quantitative and qualitative methods of analysis.

Introduction

In neuroscience parlance, the part of the brain which functions intuitively i.e., sub-consciously, is termed System 1; the more conscious and logic-oriented part of the brain is termed System 2.

In their conscious states (System 2) our brains process just 40 bits per second; in their sub-conscious states, (System 1), they are capable of processing 11 million bits per second)[1].

The numbers are approximate and should not be taken too literally. The key point to note, however, is the very significant difference between the processing power of the brain in its conscious (System 2) and sub-conscious (System 1) states.

Most traditional market research techniques focus on capturing articulated responses of consumers - essentially the System 2 conscious responses - to TV advertising. What they should do, however, is access System 1 responses, which contribute to more than 90 percent of our decision-making.

These days, there are signs that the marketing industry is increasingly alert to the importance of System 1 subconscious influences on consumers' decision-making.

This appetite to understand consumer brain responses is complemented by scientific advancement in the field of neuroscience. Innovations enable effective understanding of the dynamics of System 1 and offer the means to capture brain responses.

Electroencephalography is currently the top technology in this domain, with its simple and non-intrusive means of capturing System 1 responses.

Furthermore, new techniques and devices are evolving to better understand System1 responses based on EEG data. Independent Market Research Agency Kadence International has developed a unique neuroscience proposition.

Known as K-Web (Kadence Window to the Eye and Brain), it is essentially a methodology to evaluate responses to TV commercials. K-Web combines rational responses to TV commercials with advanced neuroscience techniques, EEG and eye-tracking. This enables detailed understanding of respondents' engagement with an advertisement and, in turn, its effectiveness.

Kadence International's Research and Development division uses Neurosky Mindwave mobile, a 512Hz single-array EEG device, to produce electroencephalograph-based brain-state analysis. An application, Myndplayer Pro, extracts data from the EEG device, as well as separate second-by-second attention and meditation scores.

It is these attention and meditation scores that distinguish the K-Web product, providing second-by-second analysis of respondents' engagement in an advertisement. This enables the success and weaknesses of advertisements to be measured at specific points and for modifications to be made.

To further develop the proposition and to underpin its ongoing and future credibility, Kadence International commissioned Hochschule RheinMain University of Applied Sciences and Neurofit GmbH to conduct detailed evaluation of the K-Web approach.

Their research finds that K-Web, using raw EEG data to define brain states, improves on Kadence's former methodology, which relied on generic attention and meditation scores. K-Web now delivers a second-by-second brain-state classification with a new algorithm, purposefully developed to evaluate responses to TV commercials.

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The Science Behind

Researchers suggest that EEG offers an unobtrusive means to monitor dynamic fluctuations in cognitive states, task engagement and cognitive load.

The temporal resolution of EEG allows precision calculations per each half or full second of data. Validation and interpretation of changes in a cognitive state, on a second-by-second basis, will be made possible using a multi-array device.[2]

As per international standards, EEG can be categorised broadly into the following bands:

FREQUENCY BAND	ASSOCIATED UNDERSTANDING OF BRAIN ACTIVITY
Delta	Deep sleep / hypnosis
Theta	Deep relaxation / day dreaming / access to memory
Alpha	Relaxation / drowsiness / phasic blocking of information coming from the outside / vigilance / general non-focused alertness
Beta1	Focused attention
Beta2 (Hi-beta)	Over arousal, panic and anxiety
Gamma	Binding processes between distributed cell arrays / Motor Functions

The beta band is divisible into two or more sub-bands, each reflecting different functions when stimulus is perceived and processed by the brain. These are just some of the understood functions of frequency bands on internal brain communication.

For the purpose of TV Commercial (TVC) evaluation, only the Delta, Theta, Alpha, Beta1 and Beta2 bands are considered relevant. However, as these are not sufficient for categorising brain states induced by watching TVC content, the authors also adopted NASA's Task Engagement Index.

NASA's task engagement index

NASA's Task Engagement Index (TEI) was originally used in flight simulators to train pilots. TEI indicates the amount of engagement with external stimuli, measuring levels of stress experienced when handling different scenarios.

TEI was first computed by Prinzel et al.[3,4] They developed an EEG-engagement index, based on beta power (13–22Hz) divided by alpha power (8–12Hz) plus theta power (5–7Hz). They reported improved performance during a vigilance task when the EEG engagement index made changes to the stimulus.[5,6,7]

Effectiveness of a single electrode EEG device

It is evident, in most published content on EEG, that a multi-channel conductance typically measures electrical activity in the brain. A set of electrodes, ranging from one to 128 in number, delivers information on how the brain reflects and processes a concrete situation or stimuli. There has long been debate on how many electrodes are needed to give an insightful glance into the brain's work. Such debate, almost without exception, relates to specific subject matter, such as the recognition of seizures in epilepsy.[8,9]

Multi-channel electrode systems not only deliver more information but, by understanding where in the brain the electrical activity will occur, fewer electrodes are needed to do the job. For instance, when assessing brain processes associated with attention, the frontal and/or prefrontal areas may be the best locations to site the electrodes that measure activity.[10]

Existing research reveals a strong correlation between the number of electrodes used and the completeness of a concrete research project. In the initial stages, a multi-channel system is mostly used, becoming a single channel device for reasons of convenience as the project progresses.[11]

In recent years, a number of single-channel EEG devices have come to market, mostly in the hope that EEG will become a measurement for different states of attention and will be used in various tasks requiring control over external systems. Given high production volumes, these single channel devices tend to be low-priced and offer relatively easy means of measuring brain activity. Younger researchers, in particular, have begun to test these devices for their scientific potential in the field of cognitive neuroscience.[12], [13]

Academic literature on EEG reveals that data from EEG devices is analyzed according to the EEG bands described in the table above. By applying EEG frequency bands, second-by-second evaluation of brain states can be derived.

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Research Objective

The research sought to identify an analysis strategy to apply to single-channel EEG data, based on regular practices in the field of EEG research. In identifying that strategy, the authors needed to be mindful of subjective interpretation of the data and to not overestimate the results.

Research Methodology

1. Stimulus Preparation

The stimulus contained eight video segments, a TV programme; five recently launched TV commercials (TVC) and two static videos (white noise) were compiled in one clutter reel, in the format illustrated below.

To interpret human-response brain patterns during exposure to the clutter reel, developers included the TV programme in order to:

- Create a realistic TV viewing experience for respondents
- Get respondents accustomed to the brain-map and eye-tracker set-up before running the static videos. This helps to deliver better quality data.

According to Berka et al: *"At first, it is necessary to define a set of relatively pure tasks that consistently elicit the targeted cognitive states to validate the methods for cognitive monitoring. Validation of cognitive state measures generally involves experimental manipulation of task demands to induce cognitive state changes, objective measurement of performance metrics (e.g., accuracy, reaction time) and subjective measures that allow participants to describe their perceived level of difficulty as well as the amount of effort exerted in a given task. The cognitive state measures must also be validated across participants and adjusted to account for individual differences when required".*

Static video sequences sandwiched the five TV commercials, giving the researchers a simple pre- and post-baseline by which to assess the state of respondents' non-specific attention before and after presentation of the specific stimuli.

2. Data Collection

One hundred main subjects and 10 buffers were recruited to watch the stimulus, while EEG data was collected using standard procedures on a single-array EEG device.

3. Data Preparation

The data underwent the following processes:

1. Band Pass filter – To extract data within the relevant frequency band

2. DC bias removed using DC offsetting – Achieved by subtracting the mean value of the EEG per second.

3. Synching with eye-tracker data – This gives data for each individual video segment per respondent.

4. Quality check – To eliminate data sets where any video segment has more than 10 percent of artifacts.

7

EEG sequences were marked as artifacts where raw EEG signal values fell outside an interval ranging from (128)µV to (-128)µV. The interval length was determined by visually checking the raw EEG. These steps comply with the methods of EEG measurement, as outlined in The Fundamentals of EEG Measurement in the Measurement Science Review.

4. Data Analysis

Using band pass filters, we obtained data for the five standard EEG frequency bands. We analysed every subject's response data for every video segment.

Collating the results of all subjects, we arrived at overall second-by-second data relating to brain-state responses to TV commercials.

Research Findings

Watson, Clark and Tellegen defined a Positive or Negative affect' schedule, as shown in Fig 3, enabling us to conceptualise five brain states, based on the amplitude of the five standard EEG frequency bands and corresponding TEI throughout the duration of the stimulus.

Positive affect (PA)	Attentive, interested, alert, excited, enthusiastic, inspired, proud, determined, strong, active
Negative affect (NA)	Distressed, upset, hostile, irritable, scared, afraid, ashamed, guilty, nervous, jittery

Fig 3: Positive Affect and Negative Schedule (PANAS) (Watson, Clark and Tellegen, 1988)

For simpler and better usage of the standard frequency bands described above, the term 'Brain states' was introduced for specific brain activity and attention patterns. The five brain states are defined as 'sleep'; 'detached'; 'partial cognition'; 'cognition'; and 'confused':,

Sleep

INTERPRETATION

The subject is not focused on any 'external' event or stimulus. The focus of attention is completely 'internal'. The dominant frequency is 'Delta', with very low 'Task Engagement' and the brain state is therefore labelled 'sleep'.

RELEVANCE

The stimulus, at the given frame in the video segment is extremely uninteresting and induces passivity.

Detached

INTERPRETATION

The subject is not focusing exclusively on any 'external' event or stimulus, nor is the focus of attention completely 'internal'. In terms of frequency, 'Theta' is dominant and the brain state is labelled 'detached'.

The Theta frequency is associated with communication processes between the functional structures of the brain. The EEG Theta predominantly indicates 'memory writing' and 'memory recall', especially when TEI is very low.

However, where both 'Theta' and 'Delta' are dominant, with moderate 'Task Engagement', it is more difficult to categorise the brain state.

Nonetheless, given the simultaneous presence of 'Delta' and 'Theta', it suggests that a very small amount of outside stimuli slips through the brain's 'mind wandering' shield. As such, the brain state may be categorized as 'detached'.

RELEVANCE

1.The stimulus is uninteresting or redundant, drawing the subject into other thoughts.

2.The earlier video clips were highly thought provoking, retaining the subject's attention.

Partial cognition

INTERPRETATION

The subject is not focused on any 'internal' event or stimulus, nor is attention completely resting on 'external' stimulus. Typically, there is a mix of the Theta, Alpha, Beta and Beta2 frequencies, which may show up in different combinations.

RELEVANCE

The stimulus, at the moment, is mildly engaging or the stimulus is too simple/redundant, only earning respondents' partial interest.

Cognition

INTERPRETATION

The subject is not focusing on any 'internal' event or stimulus; the focus of attention is completely ‘external'. The dominant frequency band is Beta1, with a positive and moderate value of 'Task Engagement’

RELEVANCE

The stimulus is interesting and understood with ease. Hence the subjects are well engaged.

Confused

INTERPRETATION

The subject is not focused on any 'internal' event or stimulus; the focus of attention is completely 'external'. Beta2 is the dominant frequency band, with a high level of TEI indicating a state of stress

RELEVANCE

There is high awareness of the stimulus, yet it is ambiguous. The subject has to work at extracting meaningful interpretation from the stimulus.

Conclusion

During every second of the TV commercials, subjects' reactions were monitored, analysed and classified, according to different EEG frequency bands and TEI, into one of five states.

The insights serve as a guideline. Deeper and more subjective understanding of the probable causes of the resultant brain states is needed to make appropriate recommendations on TV commercials.

They give an indication of how subjects perceive and interpret different frames of TV commercials. In turn, this gives actionable insights to TV commercial producers, pinpointing where they might improve specific frames in TV ads to better engage the audience, without reworking it entirely.

Scope for Further Research

As the new K-Web methodology continues to be used to evaluate TV advertising, newer insights may emerge.

Newer patterns of brain states might improve the assessment and diagnosis of commercials, reducing the need for subjective interpretation of the possible underlying reasons for a particular brain state at a particular second. Brain states may have to be redefined and new brain states may emerge.

By keeping track of data findings in K-Web projects, and reviewing norms, the methodology will be enhanced and become increasingly relevant to TV commercials.

For now, Kadence International uses a single array device. Research is underway that will allow a multi-array device to deliver more advanced results and insights that move us beyond the five current brain states.

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Researchers

The research and development team at Kadence International commissioned two experts to undertake research into brain responses to TV commercials, using raw EEG data.

Dr. Axel Kowalski
NeuroFit GmbH, Krefeld, Germany

Founder of NEUROFIT GMBH, an institution dedicated to neuroscience-based psychotherapy, Dr Kowalski has a decade-long experience in psychology and neuroscience. He is actively involved in research into electroencephalography, bio- and neuro-feedback.

Among his research projects are:

- Applications of bio- and neurofeedback in neuro-rehabilitation
- Treating ADHD with neurofeedback in clinical settings
- EEG and attention measurement
- Priming phenomenons measured by EEG.

NeuroFIt owns two practices that treat clients with conditions ranging from ADHD, migraine and headaches to post-traumatic stress disorder. The NeuroFit academy lectures on neurofeedback, biofeedback and uses neuroscience principles to derive better understanding of stress and stress management in corporate entities.

Prof. Dr. Gernot Heisenberg
HSRM, Wiesbaden, Germany

At the RHEINMAIN UNIVERSITY OF APPLIED SCIENCES, in the Faculty of Design, Computer Science and Media (DCSM), Professor Heisenberg researches brain-computer interfaces (BCI). He has a M.Sc. in Physics and a Ph.D. in Computer Science. His research expertise is in commercial EEG applications, as well as in media management.

His current research projects include:

- Evaluation of the impact of TV commercials using EEG and electrodermal activity (EDA) measurements
- Bio- and neurofeedback software development for mobile devices
- Bio- and neurofeedback software applications for the preventive treatment of stress-related diseases.

Prof. Heisenberg lectures on the technical and psychological aspects of product advertising and product placement.

In addition, he teaches search-engine techniques and search-engine optimisation, as well as findability methods in classic web, social media and web semantics.

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