N400 elicitation in semantically incongruent interaction using detailed narrative virtual worlds.

Nicholas Anton Borkowski

February 14 2014

Aalborg University Copenhagen

Table of Contents

1. Introduction

The importance of an interactive system being sympathetic towards the perceptive and cognitive abilities of a user can be considered success criteria when dealing with both traditional (e.g. film) media and digital interactive media [1]. This ensures that the communication present between system and user can function at an efficient level that is also tolerable for the user. Also, this addresses the area of symbiosis between system and user as a sort of sweet spot, allowing for research and theory to be applied to the perpetuation and efficiency of this symbiosis.

Traditional theories of this relation focus on media such as film or literature. These traditional media can carry the common bond of narrative. The narrative ties together the succession of information passed on to the user in order to communicate information in the desired structure of the author. Herein lies the importance of the semantic and cognitive connection users make to the structure of narrative. It is through these connections that users may comprehend potential interactive aspects of a given media.

Now, interactive media continues to grow as an accepted form of media consumption. Not only do users passively interpret, such as with a literature or film, but can now actively engage the media by providing input to the system. This causes problems in regard to the aforementioned established theories of narratives in media. Will the author's intended meaning shine through? Or is it to be shrouded by the intentions and actions of the user? There are solutions that can be perceived as a form of balancing act. Provide the user with options, but maintain a rigid course throughout the system.

From a cultural entertainment standpoint such narrative systems are prevalent. Narrative systems may also be utilized in different cases, such as in social media, but are not necessarily as demanding of the user to engage with interactive input as with modern video games. Although social media narrative systems may be of interest they are delimited from this work which encompasses only audio video media with interactive capability in its most broadly known and documented form namely video games.

The aforementioned systemic *symbiosis* and the established field of Human Computer Interaction are overlapping. System affordance, interaction and utilization have been a field of interest since the birth of the personal computer and the concepts of interaction design and user experience.

Narratives are an integral part of how we perceive and make sense of our own realities. We encapsulate our lives in stories in order to process them and reflect upon them [2].

It has also been tradition to attempt to quantify interactive feats within objective realms, such as the options of a chess game within mathematics. Where already in the early 20th century there was interest in valuing chess moves without need for subjective psychological analysis [3]. In consideration to modern norms where complex interactive games and systems are rampant, (Facebook, Call of

Duty) theories to better understand such topics as theories of games such as ludology and continuation desire have been established.

The narrative implications of system interaction will be brought forth and discussed. Herein lies also an interest in different interpretations of theories regarding games due to the growing versatility and abstraction of games and the implementation of aspects of different game theories in alternative fields (education, economics, etc.).
The following pre-analysis will explain the established theories in regard to the cognitive roll of interaction and narrative within games. It is of interest to explore the possibilities of testing the congruency of the narrative / interactive relationship that is representative of the interactive media. Methods for this manner of test will be suggested and explored in regard to physiological user feedback during an interactive experience.

1.1 Methodology

Within this thesis, past research within the delimited areas of interest will be explored. These will concern the standing theories in respective subjects of research. Using these established theories, a new theory will be established within the context of the given problem statement. This theory will then be tested practically using the available tools. The objective is to determine if the theory can be proven using EEG (electroencephalograph) equipment. After a pre-analysis of the topics of interest a focus will be found and a subject relevant to the findings will be elaborated upon. Thereafter test criteria will be found and implemented.

2. Pre-analysis

2.1 Narratives

Fundamental narrative structures consist of a linear story line and a discourse or plot, which is how the story is told to the recipient [5]. With this in mind there are many structures by which one is able to communicate the same story, or portions of it, to an audience. Similar to traditional media such as film, videogames can commonly be broken down to a narrative containing three acts. These three acts are an initial introduction to conflict, a quest for resolution and a conclusion [4].
It can be established that the interactive elements of a game can have consequence to the discourse of the narrative. The interaction from the player

determines the overall subjective understanding of the discourse of the narrative. For example, if a videogame takes one player 1 hour to complete and the same game takes another player 2 hours to complete, their ultimate subjective interpretations of the same intended narrative can vary.

2.2 Interaction

Within videogames, the game's author universally dictates the degree to which a player can interact with the game. The author decides how much influence the player may have on the game world. The affordance of more interactive capability within the game can be accompanied by a continuation in the discourse of the narrative. This is a quid pro quo system, in which the player is either granted new interactive powers due to your adherence to the intended narrative discourse, or you are granted new narrative discourse due to the actions performed within the interactive scope allowed to you by the author of the game.

For example, when starting a videogame, the controls are communicated to the player, thereafter, the combinatorial possibilities of the afforded interaction are explored by the player and through these explorations the narrative discourse may progress.

The narrative discourse may continue after the player experiences a repetitive-interaction process. Requiring the player to conduct repetitive interaction, that reinforces their understanding of the limitations of the interactive capabilities, may also have value to the author's desired narrative outcome. Even though this is an area where the interaction and narrative of a videogame can correlate, the player's repetition of the interactive affordances does not necessarily contribute to the discourse [4].

This interactive repetition does contribute to the *subjective* discourse (or: overall experience) of the player. It is here, in the overall experience, that the balance of interactive capability and the communication of the intended narrative becomes a fragile area for a designer/author to address. There can also be an authorial desire to elaborate interaction over story or vice versa.

This can be explored in way of looking at the different signaling systems utilized by the designer/author of the game. Such systems must exist both in regard to communicative processes alluding to interactive options and narrative cues. It is possible that narrative cues are used to communicate both narrative continuation and interactive affordance to the player.

2.3 Semiotics

Semiotics is the study of signs and how they can be defined and interpreted. How these interpretations can manifest cognitive meaning to an audience is especially important when considering hybrid media such as videogames. Visual, auditory, kinesthetic and sometimes haptic signs and signs consisting of combinations of these sensory inputs are found in modern videogames and interactive systems. A sign can consist of a signifier and a signified [6]. Where a signifier can be an object, and the signified is whatever correlates to that object from the interpreter's point of view. For example a tree can be a signifier while its signified can be *tree, green, nature, wood* virtually anything that an observer can extract from the signifier can constitute the signified. While the signified tree represents the sign in the most obvious sense, interpreting the tree as *The Tree of Life* would require additional cultural connotations. A tree denotes *tree,* while it may connote *Tree of Life* or *life* [4]*.* This is a valuable distinction. As claimed by Peirce this inevitably invokes an infinite number of interpretations and continuations on a given sign. A sign can be transformed from its most apparent and obvious meaning to the outreaches of one's imagination due to a limitless number of potential connotations. Though this is expanded in relation to a dynamic object and an immediate object, the former being the object that generates the chain of connotative signs, while the later is what the subject believes the sign to be at the specific time of exposure [8].
Works of art can be distinguished in a similar manner. Works can be thought of as a sequence of signs designed to come in a specific order and have an effect. It then depends on the viewers of the work to communicatively receive it in their own unique way and apply their own methods of understanding to the work. A work of art can be interpreted differently. But each interpretation can be seen as a "performance" of the work. And the acceptance of the work may depend on how many different viewers can see it from their individual perspectives and still understand the intended signals [9].

Understanding these concepts is important when attempting to address the psychological and cognitive aspects of combinatorial stimuli found in modern interactive systems. Being able to manipulate these aspects of gameplay within videogames is important in order to communicate effectively both the narrative and interactive ambitions of the system.
Gameplay is defined by the Oxford English Dictionary as "The action or process of playing a game or games; game-playing. Also: the manner in which this is done;[…]" [21]. When used in this writing the former definition will apply. It is important to notice that the latter meaning referring to the *manner* in which the game is played alludes to a very subjective experience reliant on the communicative aspects of player and game.

2.4 Flow and Gameplay

These balancing acts of narrative and interaction can be compared to those of flow. Flow is the balance of *challenge* and *ability* that allows a user, or player, to find a comfortable level of endurance with a system and receive a gratifying and continuously pleasant experience [10]. Achieving the feeling of "being in the zone" includes 8 factors according to Csikszentmihalyi.

• A challenging activity requiring skill;

• A merging of action and awareness;

• Clear goals;

• Direct, immediate feedback;

• Concentration on the task at hand;

• A sense of control;

• A loss of self-consciousness; and

• An altered sense of time.

These factors mediate a flow zone in the task at hand. In regard to games specifically, Chen [10] describes the following criteria for designers to adhere:

- *"Mix and match the components of Flow*;" (create a suitable balance of the aforementioned 8 factors.)

- *"Keep the user's experience within the user's Flow Zone*;" (Provide the user with a balance of challenges in regard to their ability and therein; their capabilities within an interactive environment.)

- *"Offer adaptive choices, allowing different users to enjoy the Flow in their own way; and"* (Utilizing the 8 factors of flow to balance an interactive experience so that players who seek alternative experiences, are able to find their personal flow zone.)

- *"Embed choices inside the core activities to ensure the Flow is never interrupted."* (Core activities are loosely defined as the game mechanics of a given game. Game mechanics are the authorial balances of the interactive capabilities. Being able to run, jump and shoot in a videogame can be entertaining, but it is the relationship of the three interactive capabilities and how they are able to complement each other, that constitute game mechanics. It is through these interactive capability inter-relationships that allow the player to eventually become skillful in their combinatorial use.)

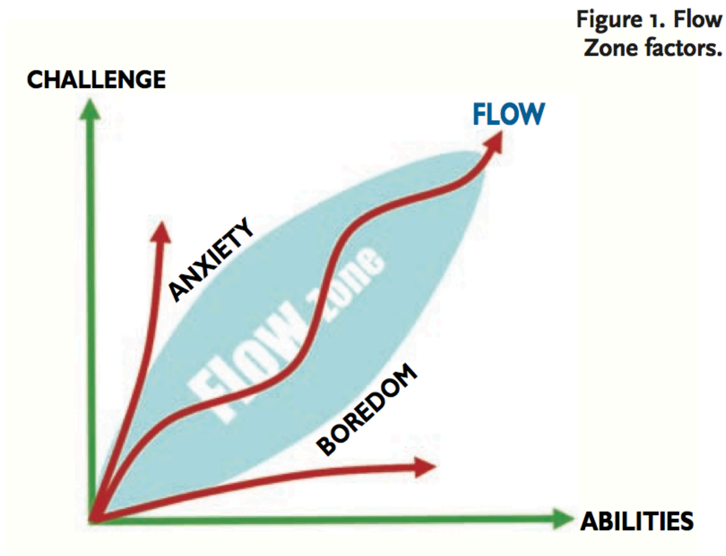

Figure 1 Visualization of Flow-zone from Chen [10]

These theories entail that the importance of maintaining a zone of flow is critical to the enjoyment of a videogame. This however is a careful act that requires many areas of design and balancing of both narrative and interactive elements. These elements must also correlate and support each other for the successful creation of a flow zone and its continuation. Accomplishing this can of course be approximated using both narrative and interactive curves throughout a game but it can also allude to the area of adaptive environments; creation of systems able to learn from user interaction and subsequently change aspects of flow in order to adapt to the user's specific flow area.

An alternative view is that of gameplay gestalts [11], these can be thought of as constructions of flow paths. These are also thought of as gestalts composed of a narrative and interactive areas. Where an interactive action does not necessarily influence a core aspects of the narrative and the repetition of certain interactions wont either. Though both narrative and interaction continue on a linear path of rising complexity, as the story expands and becomes more elaborate, the interactive capabilities expand and increase in complexity. This is a correlation that may be found between the two realms of narrative and interaction.

"Gameplay in itself has remained a very vague notion in the literature to date, making it difficult to understand what is being juxtaposed with narrative. A gameplay gestalt, however, as a pattern of perceptual, cognitive, and motor operations, is not only more specific, but could perhaps be measurable in terms of the perceptual, cognitive, and motor requirements of performing it. It may in fact be possible to classify games according to their required effort in the gestalt

dimensions of perception, cognition, and motor performance." [11]

Perception, cognition and motor operations are the factors that create the gameplay pattern. A gameplay pattern may or may not initiate flow within an interactive experience. But such a pattern can be a useful theoretical tool in order to approximate a flow zone within a videogame.

Being able to understand how a flow zone can emerge from a gameplay scenario is crucial to understanding the ways in which videogames function. These flow zones can be created with games that have very strict coherent stories but also from more abstract games that focus on interaction.

So far it has been established that a videogame can hold both narrative and interactive aspects that can be analyzed separately. Furthermore, certain narrative cues can inform the player about how to interact with the videogame. This also allows for certain interactions to correlate to, or expand upon, the videogame's given narrative. Through these crossing relations, both the gameplay and the flow of the game arise. If one were to argue the merit of these crossing relations, or infer that the interaction and narrative of a given videogame are separate entities, another theory, gameplay gestalts, is applicable. Gameplay gestalts may arise alone from linear continuation of heightened complexity from the narrative and the interaction. Keeping in mind that linearity is not a prerequisite for a gameplay gestalt. A gameplay gestalt constitutes solely a pattern across perception, cognition and motor skills. Through these terms and theories one can discuss the connections of narrative and interaction within videogames. With these in mind, there are other theories that help explain more combinatorial aspects of narrative and interaction within a gameplay experience.

2.5 Emergent Narratives and Narrative Intelligibility

An emergent narrative is when the player is allowed, via their interactions with a game, to have an influence on the overall narrative experience using the narratological tools provided. This can result in different narrative elements being accentuated by the player [12].
Carving out space for the player to influence the narrative can also lead to methods of interaction unforeseen by the game designer, which entails *Emergent Gameplay*. Emergent gameplay encompasses not only the emergent narrative but also the emergent interactive choices possibly unforeseen by the game designer.

Allowing a gameplay to become emergent may be a sign of a designer's attempt to create an experience with space for *individual* flow zones to occur. Not only flow zones preconceived by the designer.

For example, beyond being granted the interactive capability of being able to run and jump in a game, a player may be able to decide his or her own narrative direction. Meaning that the player creates their own surrounding narrative, rather than choosing one of many possible designer-intended narrative paths.

Figure 2. The Sims 3. Emergent Narrative. [16]

The above image represents a construct that a player of the game Sims 3 created. They have constructed a maze around the house in which their Sim lives, causing them to constantly be late for work and sleep deprived. The developers of Sims 3 did not necessarily have these kinds of constructs in mind. But it is possible for the player to get a sadistic laugh creating such worlds using the emergent structure of the game.

Emergent gameplay, on the other hand, would be for example if a player were to find solutions, unforeseen by the game designer, to in-game challenges. Such solutions may cause the player to circumvent certain challenges intended by the designer, yet maintain the overall narrative structure of the videogame.

2.6 Closure

The notion of emergent gameplay can be related to that of narrative intelligibility and narrative closure. Being able to understand a game designer's intended narrative and also how it may be possible to influence that narrative is intrinsically connected to how the available possibilities of narrative structure are communicated to the player. Narrative closure and narrative intelligibility are concepts that create space for understanding and analyzing interactive narrative possibilities.

If a videogame player were to subjectively process the overall goal or completion of the communicated narrative independently of authorial intention, it amounts to narrative closure. Narrative closure is achieved when a subject (in this case a videogame player) creates meaning from a mediated work independent of the author's intentions, even if the meaning created by the player does not correspond to the intentions of the designer [13]. Players may therefore be able to achieve narrative closure regardless of a designer's intentions to allow emergent narratives or emergent gameplay to arise by creating their own perceptions of narrative within the interactive constraints of the game.

Narrative closure happens once the subject gains meaning from a mediated work, this is regardless if that meaning is the same as what the author intended.

2.7 Intelligibility

Narrative intelligibility is defined as: "*the audience receives or generates meaning in a way that is close to what is intended, desired or expected by the author*" [13]. A videogame player plays the game and understands the intended narrative. The designer has been successful in communicating their intended narrative.
But with the possibility of emergent gameplay and the options afforded to the player through the interactive capabilities of the game, no subjective gameplay experience can be exactly alike. Narrative intelligibility only entails that the player receives the intended narrative. How this narrative is received subjectively is of little consequence of the success of narrative intelligibility.
There is also intelligibility at a systemic level [13]. This allows for the concept of intelligibility (deriving meaning from a mediated work in similar fashion to that which was intended by the author to be derived) to be applied to the interactive realm of videogames.

2.8 Narrativity

Video games do not necessarily have to contain linear story lines that must be followed. Though it is possible for a subject to project his or her own story onto an interactive media. If a narrative can be extracted from an interactive media then that media is thought to possess narrativity. Narrative extraction from abstract stimuli can be considered emergence as well.

Since emergence may allow for players to change aspects of a narrative, or solve challenges in new and different ways, a subjective understanding of the game and its narrative space is constructed in which the constraints of the system are applied. Within videogames, narrative structures can be supported by interactive conditions, influencing the player to make decisions based on the goal oriented nature of a specific system and informing them that it is the most effective way (or only way) in which to progress the narrative.
This notion leaves space for an overlapping area of interpretation that allow

players to interpret a gameplay that exists somewhere within the combination of the interaction and narrative they experience. Such an area must include all interactions with the system (e.g. a videogame) as influential on the intended narrative of the system.
When considering that designer's can incorporate interactive opportunities that may strengthen, or add to the linearity of the intended narrative it may be possible to create a notion of a *flow zone* not between challenge and ability, but between narrative and interaction. Such flow zones would exist within interactive media that have imbedded narratives.

In review:
Narrativity – The possession of narrative capability.
Emergence – It allows space for narrative elements.
Intelligibility – It is the established space for narrative elements to transcend.

2.9 Low intelligibility, High closure

Relative narrative constructs have been addressed within work documenting *narrative closure* and *narrative intelligibility,* where certain interactive systems can be structured on a balance of the two. While some systems may contain low intelligibility and high closure, others may contain high intelligibility and high closure [13]. It is important to note that the two forms of narrative understanding are not trade offs. They exist together and systems can exhibit variant levels of balance between the two.
A videogame that lacks narrative intelligibility could provide closure to its player via high systemic intelligibility. Yet this systemic intelligibility may still depend on narratological cues in order to communicate the necessary systemic affordances to the player.

Examples:
Perhaps, in some cases the intelligible narrative outweighs the interactive affordances and a player may find himself guided along throughout the story, without much opportunity to deviate from the intended narrative.
Other cases might involve reverse proportions, where the interactive affordances outweigh the direct intelligible narrative. In such cases, it would be up to the player to either;

- Fill in the blanks left in the intelligible narrative by the designer (in ways intended or unintended by the designer), or
- Create their own narrative (bound solely by the provided realm of interactive affordance).

Herein lay the cohesive elements of interactive story telling and player affordance. Since both elements play a role in communicating the intended authorial message, both traditional narrative and the interactive capabilities afforded the player by the author continue along a coherent path which concludes with the player achieving narrative closure as the desired outcome.

A narrative can A. be intelligible, or B. provide closure.
While the *interaction* can be interpreted as A. intended, or B. emergent.
Where "*interaction*" should be read as: the combinatorial possibilities of the afforded interaction.

3. Analysis

3.1 Narrative Coherence

Taking into account the four aforementioned factors of narrative intelligibility/closure and interactive emergence/intent, some constructs of these elements may not provide any of the four factors very well. This means that even though a video game may provide low narrative intelligibility and high closure, it may not deliver this to the player very well, causing the player confusion or distress.
Unlike measuring a balance between intelligibility/closure and intended / emergent, these factors are not interchangeable, but combinatorial. Narrative Coherence is not a notion of most sustainable combinations. Narrative coherence is the realm in which the combinations of the factors may provide flow to the user. Flow providing combinations can be considered narratively coherent digital interactive systems.
So in what way is it possible to assess the narrative coherence of a videogame?

If one were to delimit the goals of the player to that of narrative closure (regardless of its manifestation through emergence or intelligibility) it is crucial to the experience to provide constant prevalence of narrativity. This allows the player to experience a form of consistency. It is through this consistency that the player is allowed to consume new narrative and learn new interactive capability.

The interactions of a player can possess narrativity, just as other signs and signals from an interactive experience can. This can also transcend emergence, whether interactive- or narrative-emergence.
A prerequisite of prevalent narrativity is either an intelligible narrative or an intelligible system. This is because the videogame must uphold a communicative bond with the player.
This bond of narrativity is similar to a flow zone. The relation of narrative and interaction, rather than the relation of challenge and ability, describe this bond. It is a balancing act of narrative and interaction that must continue on an onward path. The narrative in this sense is either intelligible by authorial design or subjective closure. The interaction is bound by the same guidelines, either consisting of intended design or emergent gameplay.

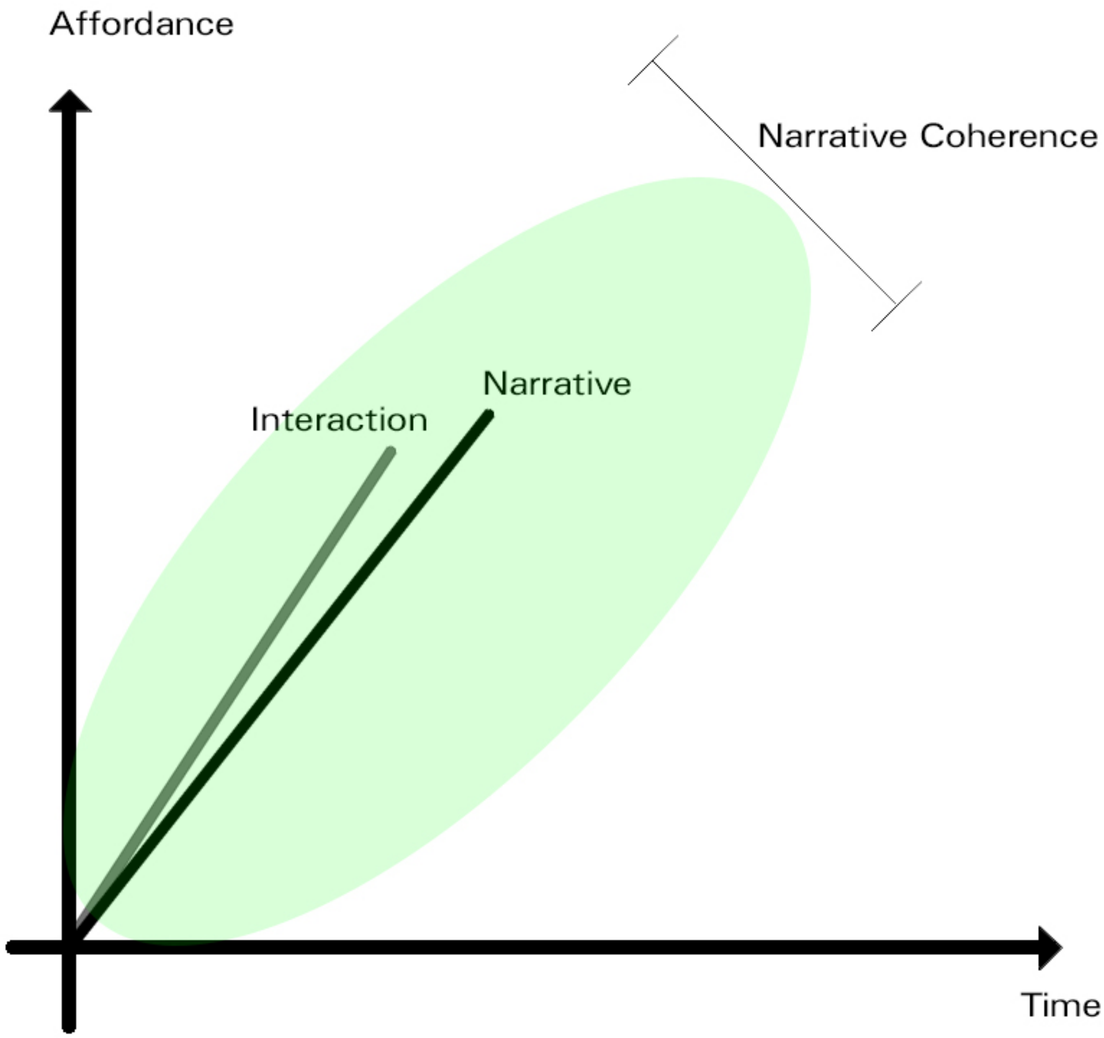

Figure 3 Narrative Coherence. Depicted similarly to Flow. In this case, the lines representing Narrative and Interaction are not a representation of any specific instance, but an illustration of their place within the model. Their approximation to one another is representative of their collaboration, therefore upholding a coherent narrative experience.

In the above image, Narrative Coherence is set up in a similar fashion to that of a flow zone. Within the light green ellipse, the subjective narrative experience is most coherent. Within this ellipse are the two separate, ongoing experiences of narrative and interaction. It is important that a balance is maintained between the two. If one deviates too far away from the other, narrative coherence is lost.

Reimagining it as a 3 dimensional graph. Narrative and interaction, respectively, would be on the *y,x* and *y,z* plane, while narrative coherence would exist on the *x,z* plane. This would represent a space within which the narrative and interaction of the given experience can intermingle and maintain a coherent relationship.

The combination of the interactive capabilities whether intended or not by the author, and the narrative whether intended or not by the author, can output four different scenarios and uphold narrative coherence. In these scenarios the bond of narrativity is not broken. It is also within these scenarios that narrative coherence differs from a flow zone.

1. Intended narrative, intended interactivity (INII)

2. Intended narrative, unintended interactivity (INUI)

3. Unintended narrative, intended interactivity (UNII)

4. Unintended narrative, unintended interactivity (UNUI)

These four scenarios are structures by which a player can interact with an interactive videogame and possibly still uphold the desired levels of challenge and ability to necessitate flow.

1. INII

The player utilizes their interactive capability in the intended manner in order to submit to the intended narrative. This scenario resembles a stringent linear narrative. The player follows the intelligible communication within the game, causing them to progress, as intended, through the experience closest resembling that of the author's intention.

2. INUI

The player understands the narrative- and interactive affordances provided by the author. Thereafter the player decides to "cheat" by partaking in an interactive action that is not intended by the author, but also circumvents the intended methods of interaction with the game. An example would be for someone to repeat an interaction, causing a visual glitch. This then becomes the emergent narrative of the player; to provoke this glitch. But this was never intended by design. This can be likened to the aforementioned definition of emergent gameplay.

3. UNII

The player is in disregard of the communicated (or poorly communicated) narrative through apathy or choice but the narrativity of the interactive capability allows the player to establish flow.

4. UNUI

The player has complete disregard for all narrative story elements and intended action that the interactive capability provides. The communicative aspects of the game are subjectively intriguing to the player and allow flow. An example would be a player realizing that pressing the pause button plays a sound effect that they then attempt to press the button fast enough in order for the sound effect to repeat in a certain way. This scenario would most likely be seen with players searching for glitches or attempting to "break" the game.

Investigating a game a certain points of interest may reveal areas where different types of narrative coherence arise. When observed, these points can then be used to reiterate the design of the game. In order to apply these theories within EEG research the following section will elaborate on the possibilities of evaluating narratively rich games.

3.2 Measuring Experience

Assessing the experience of videogame players has been done in different ways. Experiments can be conducted using qualitative interviews, quantitive questionnaires, and biometric feedback along with combinations of these methods.

Being able to assess the extent of cognitive and semiotic relations of interaction and narrative during user exposure to a given system would be crucial to trying to understand narrative coherence and attempt to create a measurable criteria that may prove it to be a viable sought after measurement during design and production of videogames and perhaps other digital interactive systems.
Game metrics is a term that covers many avenues of data acquisition in regard to gameplay and experience. There are many methods of data collection and there are different methods that can be recorded both within the game itself or recorded directly from the player. It is of utmost importance when using different types of telemetry to uphold synchronization between data acquisition techniques [15]. Collecting data from gameplay must be focused on measureable events. These events must be specific, present and observable [15]. They can thereafter be instant or duration based. Either happening within a limited amount of time in relation to stimuli, or observable throughout a specific duration of time. Because of the nature of videogames it is important to create a test criteria that is simple and therefore easy to control [22].

3.3 EEG Measurement

The use of electroencephalography (EEG) in user testing and observation has been applied in many ways. The Event Related Potential (ERP) named N400 is used to determine semantic incongruence [17]. An event related potential is a voltage variation within a continuous EEG reading that can be time correlated to a sensory motor or cognitive event [18]. The N400 name expresses that the ERP elicits a negative wave, circa 400 ms after a stimulus has been observed. The first experiments showing a N400 ERP were linguistic experiments first published in 1980 by Kutis and Hillyard [17]. Test persons were asked to read semantically inappropriate sentences, which in turn elicited a N400 response. Sentences such as; moderate semantic incongruity "He took a sip from the waterfall" and strong semantic incongruity, "He took a sip form the transmitter". Furthermore, another experiment in the same study included semantically congruent sentences ending with a word 25% larger in font size. These font size experiments elicited a different ERP, P560. Sentences with strong sematic incongruence elicited larger N400 reactions than those with moderate incongruity.

3.4 Problem Statement

Can the N400 event related potential (ERP) be used to further the understanding of cognitive activity during interaction with virtual worlds? Earlier work has found that audio-visual congruency is also linked to the N400 ERP. Is it possible to provoke the same ERP within interaction congruency? Is it possible to provoke the same ERP with hybrid stimuli (audio/visual/interactive)?

3.5 Generating N400 in response to semantic incongruities.

In order to research developmental lingual skills in children, researchers in Sweden conducted a similar experiment. Prior to testing children, they tested adults in order to create a baseline to compare future results. The participants were exposed to video and audio of simple, known objects. They used mismatching of the audio and video as semantic incongruence. Their research explains that the N400 ERP is found both in children and adults. Where in children it is more widely distributed in more areas of the brain. Their results found that the completed tests would function as a suitable baseline for future tests on children. Some limitations were met in form of several subjects eliciting the P300 ERP usually correlating to the test subject being exposed to less probable stimuli (in this case the incongruent stimuli) than that of the "normal" (congruent) stimuli. They claim that it has to do with the randomization of the order in which the stimuli was presented. They suggest that in order to resolve this issue in the future that test participants be given a task to resolve during testing.

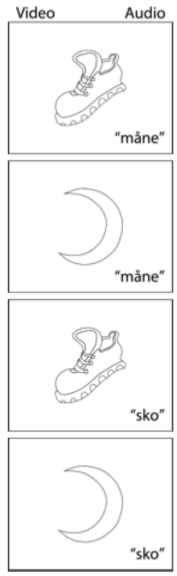

Figure 4 Examples of both congruent and incongruent stimuli in Swedish, (sko = shoe, måne = moon)[18]

Even though this study was a "pre-experiment" on only 8 adults the researches believed that with further testing, herein changing the incongruent conditions to include animated and inanimate objects, such experiments will yield a suitable baseline in order to continue research on N400 in children with autism spectrum disorders.

3.6 Recognition of actions

Recognition of images of people performing everyday tasks has also been used as criteria for eliciting the N400 ERP. Within this research it was shown that images of persons performing different tasks elicit the N400 ERP in a similar way to the more linguistically based research. Some images featured recognizable actions while others featured obscure actions. The study was conducted in order to determine if semantic violations in comprehensible actions and incomprehensible actions could elicit N400. Out of 260 pictures 130 were actions lacking a meaningful goal. The images were chosen by 10 judges and balanced within certain criteria (number of persons involved, sex, age, luminance of image). Each image was shown on a grey background for 1500ms with inter stimulus intervals of 1800-1900ms. This experiment included a task. The task was to press a button when a natural landscape without humans was presented instead of the congruent or incongruent actions. Although within the article the necessity of a conscious task is not elaborated upon, the previously discussed research indicated that it was lacking element within their study.

Figure 5 Example of images used in human action test [19]

Concluding it is stated that their findings of the N400 ERP indicate that such non-linguistic units are coded in the brain as single meaningful units. The authors also suggest that these readings are due to the incongruent actions being infrequent and rare and socially inappropriate. This is an important observation to make due to comparisons with previous research indicating that N400 readings are "[...] *more negative to pseudo-words than words and later to less familiar or frequent words than to more familiar words, but its behavior probably suggests lexical access rather than semantic integration processes*." [19 p.145] This entails that the attributes of the N400 ERP curve itself are influenced by lexical familiarity after being initiated by semantic incongruence.

This research brings the N400 semantic incongruence more towards the visual reality of daily life. Not only can the N400 be measured during word, sentence and object relations, but also for more complex pattern recognition within different recognizable scenarios.

3.7 Moving Pictures

Silent films have also been used to test the effects of incongruence on test subjects EEG readings. Within these short films, congruent or incongruent endings were introduced in order to induce N400 within test subjects.

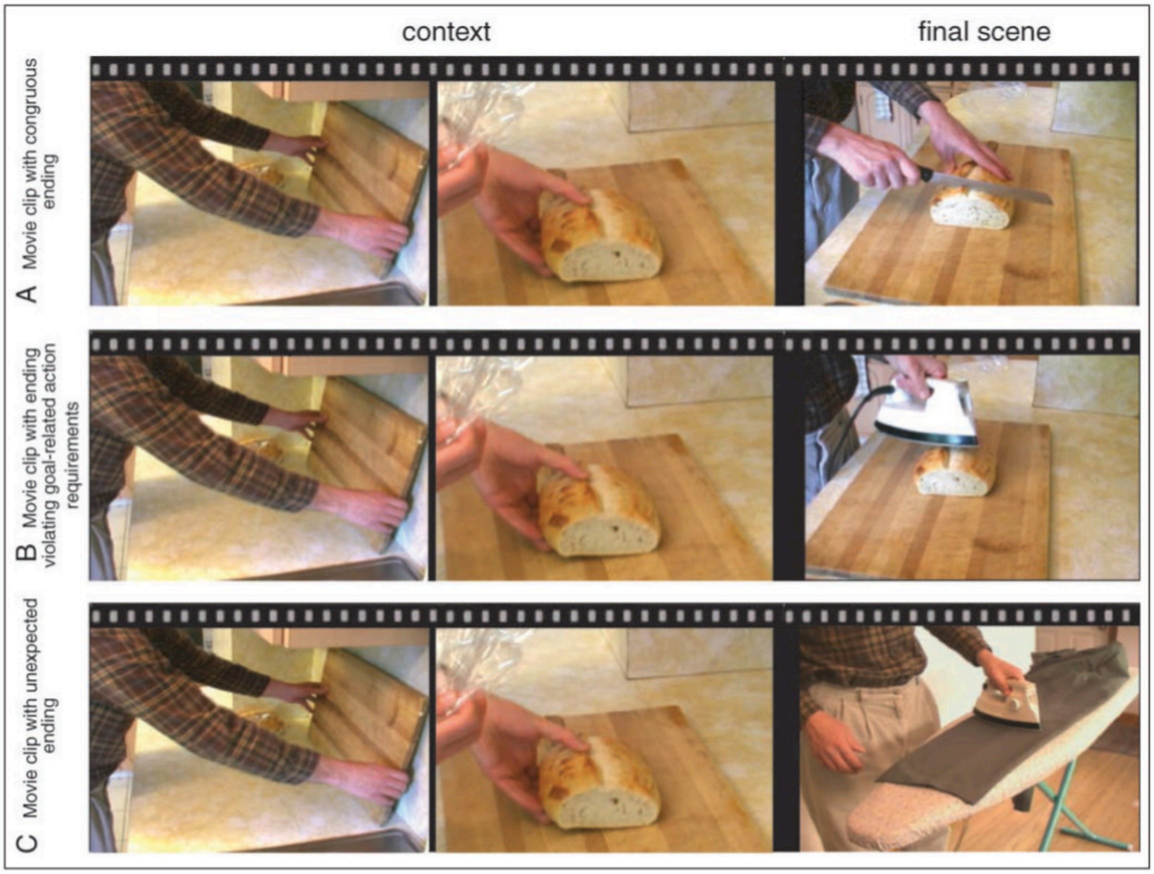

Figure 6 Two neurocognitive mechanisms of semantic integration during the comprehension of visual real-world acts. [20]

In these experiments researches created three different tests that are featured in the above figure. A movie clip with a congruous ending (A). A movie clip with an incongruent ending, which violates the goal related action featured in the beginning of the movie clip (B). Finally the third test was using an incongruent ending as well but this was not related to the goal featured in the beginning of the movie clip, it is unexpected.

"These graded connections in semantic memory networks are thought to be continuously accessed and used during on-line language comprehension, and the N400 waveform appears to reflect a process whereby the meaning of an incoming stimulus is mapped onto the corresponding field in semantic memory. The tighter the link between the representation of this eliciting item and the specific semantic- memory field activated by the preceding context, the less demanding this mapping process, and the smaller the amplitude of the N400." [20]

3.8 Delimitation

The N400 is a useful tool enabling researches to distinctly gauge reactions in test persons to incongruent media material. Being able to apply this sort of

neurophysiological experiment to digital interactive media has at this time not yet been attempted in the reviewed literature. Such an attempt would provide interesting data in regard to understanding digital interactive worlds and how the people who experience them understand these worlds.
Earlier experiments have focused on testing semantic incongruence within narrative constructs using different media approaches. Applying an N400 experiment to digital interactive media must therefore focus on the core differences between it and the aforementioned media used in experimentation. The interactive capability found in digital interactive media is that which is of interest to determine if it can elicit an N400 ERP response. This would allow for interactive capability to be a proven intrinsic asset to the narrative of a given digital interactive media. If the N400 ERP were to be found within an experiment using interactive capability as a control, it would prove that interaction has a part in the coherence of a hybrid narrative outcome within digital interactive media.
This would support the theory of narrative coherence as a valid form of narratological interpretation of digital interactive media.

The following sections will determine the practical applications involved with conducting a neurophysiological test.

3.9 EEG measurement

In the human brain lie the controls for the nervous system. These controls are managed by neurons (nerve cells) that are able to send signals throughout your body. Because of this there are constant measurable electrical signals happening in your brain. The amplitude and frequency of the brain waves varies depending on the actions of the subject.
Electroencephalography is a term used to describe measurements made on the human scalp in order to detect electrical activity within the brain. When recording EEG signals, muscle movement such as eye-blinks and jaw clenches can cause noise in the signal [23]. The placement of these sensors is determined by several different factors. The 10/20 system is a standardized model for scalp sensor placement. This standardized placement has been created in order to ensure that experiments can be recreated accurately. The name refers to the distance between the placements of the sensors. Each sensor will have a distance of 10% or 20% of the length of the skull of the subject measured from the bridge of the nose to the center of the back of the skull. Each sensor has a specific name that is representational of the area of the brain over which it resides.

The human brain consists of four lobes, the frontal lobe, parietal lobe, occipital lobe and the temporal lobe. Different sections of the brain perform different processes within the body. The frontal lobe is associated with attention and planning. The parietal lobe is associated with special understanding, the occipital lobe processes visual sense and the temporal lobe has to do with functions associated with smell, sound and complex stimuli, such as recognizing faces.

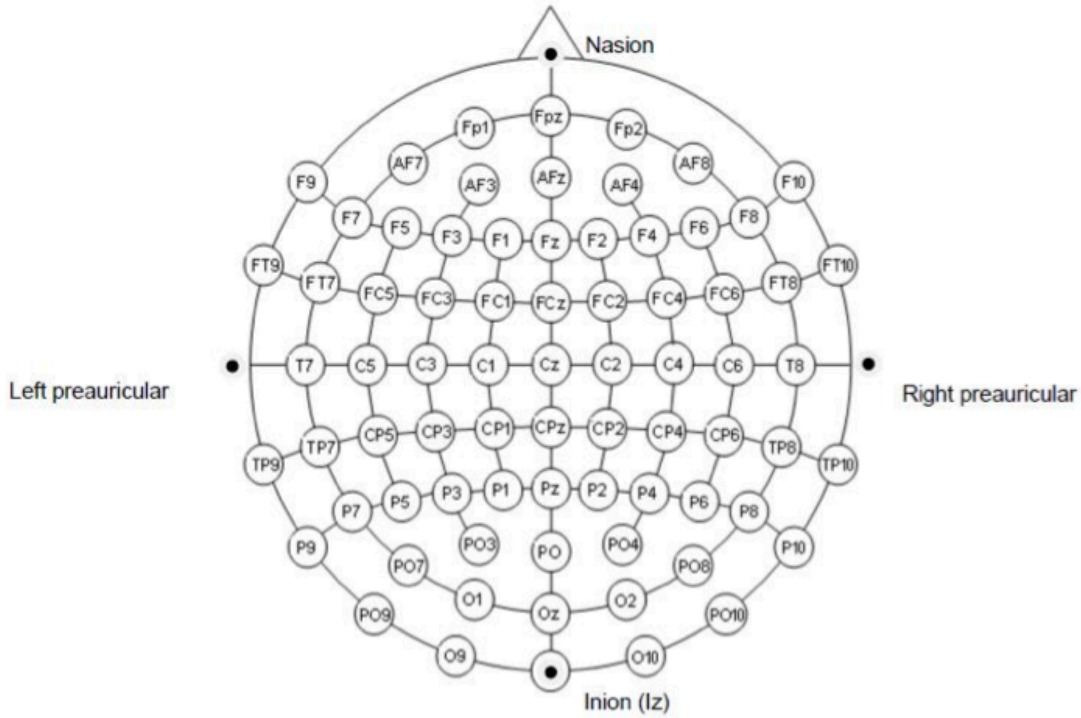

Figure 7 EEG 10-20 System.

F = frontal
Fp = frontopolar
T = temporal
C = central
P = parietal
O = occipital
A = auricular (ear electrode).

Sensor Placement

Placement of the EEG sensors for N400 detection in the 10/20 system are;
Fz, Cz, Pz, F3/T3, F4/T4, P3/T7, P4/T8 [23]. These sites may vary, but it is important to note that word-stimuli experiments focus on central-parietal and more anterior positions for experiments with images and memory load [23]. It has also been claimed that anterior sensor placement showed a more prevalent N400 with movies than with words [20]. Experimentation in regard to N400 has had to do with lexical processing, and visual recognition. Since visual and haptic experience stimulate overlapping areas of the brain, similar sensor placement setups can be taken into consideration [24].

4.0 Design

In order to construct a test that measures EEG signals during an interactive media experience an interactive media is needed. A video game in which a player can become immersed in both narrative and interaction is necessary. The video game must have detailed audio-visual design aspects but also provide different interactive capabilities that the player must become accustomed to.

4.1 Cantrip the game.

Figure 8 Image of main character in the game Cantrip.

Cantrip is a videogame produced by myself and 14 other students in late 2012 during our participation in DADIU (Danish Academy for Digital and Interactive Entertainment). The game is a 3rd person puzzle adventure game in which you play as a young orphan boy who must save his sister from an evil witch. Within the game, the boy becomes cursed by the witch and must utilize this new curse in order to traverse a scrapyard. Once the boy has managed to traverse all the obstacles in order to reach his sister he must destroy the witch and save his sister.

Cantrip is a suitable choice to work with due to its complete narrative structure, level of aesthetic detail and the availability of the source code and assets that constitute the game. The following sections will elaborate on the details of the game, its storyline interaction and content.

Storyline

In the beginning of the game you and your sister are hungry orphans looking for collectable cans that you can exchange for deposit so that you can buy food. You enter the scrapyard which the narrator exclaims "..looks like a dangerous place". You are accompanied by your sister, who is a non-player character that is humming a tune. After entering the scrap yard you are able to pick up some cans and eventually encounter an "old bag lady" that turns out to be a witch. The witch accuses you of stealing cans that rightfully belong to her and hastily kidnaps your sister and puts a curse on you. Because of your label as a thief, the witch gives you a curse that suits your crime. The curse is that all metal objects will stick to you. Once the witch has disappeared deeper into the scrapyard with your sister. The boy must try to save his sister by following a trail of cans that the sister has left behind.

Throughout the game you must use the boy's curse to your advantage, carrying metal objects to and fro in order to set off pressure switches, kill guard dogs, avoid dangerous metal objects such as scissors and saw blades and use magnetic cranes to transport you from A to B. Along the way there are relics from a forgotten past littered around the scrap yard and dangerous machines that must be avoided. Eventually after traversing the scrap yard the recognizable humming of your sister becomes audible and you know you are close to your goal. Once you find the witches house, you see that it is entirely made up of cans. You use your curse to destroy the house and caste the witch into a fiery pit, saving your sister.

Game mechanics

During the introduction of the first level, you play as an un-cursed boy. The only interaction available to you at this point is movement and collecting the cans around you that eventually lead to the witch, where she curses you. Once cursed, you have achieved the main game mechanic of the game, magnetism. By pressing the left mouse button the player is able to dispel the curse for a limited amount of time. This means that once the left mouse button is pressed, all metal objects attached to the boy's body will go flying away from the boy. When the boy "demagnetizes" he is able to avoid potentially dangerous objects flying towards him, such as saw blades and scissors. All metal objects glow with a recognizable shadow indicating that they will fly towards the player when the player gets close. If the player is very close to the objects they will begin to make a rustling noise indicating that their flight towards the magnetic boy is imminent. Some metal objects are larger and therefore require a prerequisite amount of mass before they can be influenced by the boy. This means that in order to activate a particularly heavy switch the boy must first gather lots of small metal pieces, slowing him down, before larger metal objects will react (such as a refrigerator). This interaction is presented to the player by larger objects glowing, when the boy is the appropriate mass and an onscreen GUI (Graphical User Interface) that shows: The amount of "concentration" the boy has left, the current weight of the boy and his current health.

Figure 9 Cantrip heads up display. From top: magnetism power, weight and health.

Gameplay structure

During gameplay there are several different elements that help progress the game's narrative and force the player to use their acquired interactive capabilities in order to progress. After acquiring the magnetism curse, the boy is sucked onto a magnetic crane. This forces the player to use their demagnetization power in order to free themselves from the magnetic grip of the crane. This is also the only time where the non diegetic narrator breaks the fourth wall by instructing the player to "press the left mouse button" if the player is stuck on the crane for a prolonged period of time.

The enemies throughout the game are guard dogs. The player must be quick to get past them so they add a sense of urgency to the player and also a good reason to use you demagnetization power, so that all the metal will fall off you and your speed will be unhindered by the burden of carrying metal around with you.

There are switches on the ground that act as pressure plates. These switches activate different things and require different weights to do so. There is a sign on a pole next to each switch that indicates the minimum weight necessary to activate the switch. In order to get past the first level of the game the player must activate such a switch that requires a heavy weight and then dispel their metal weight in order to get through a door way in time.

Furthermore there are heavy metal objects in place hindering the completion of the level. This creates a situation where it is necessary for the player to learn that a larger metal mass is required of the player before these large metal objects can be moved.

Figure 11 Early sketch of main character.

4.2 Test method.

4.2.1 Design

Using the Cantrip video game for test purposes is vital since even though it is a student game, it upholds qualities of known, previously experienced interactive video games. These qualities include sound effects, animation, detailed models, and coherent environmental aesthetic.
The test will be divided into two groups. In order to determine if variations in control schemes can elicit N400 ERP in test participants the first group will be subjected to interactive incongruence tests.

4.2.1.1 Group A

When the test participant reaches certain areas of the game's virtual environment they will breach an invisible trigger collider, which will change the control mapping of the game's interaction. Normally the game has six buttons that can be manipulated by the player. W, A, S, D – for character movement, Left mouse button for action, and space for Jump. Additionally the player can zoom in and out from the player character using the scroll wheel on the mouse.

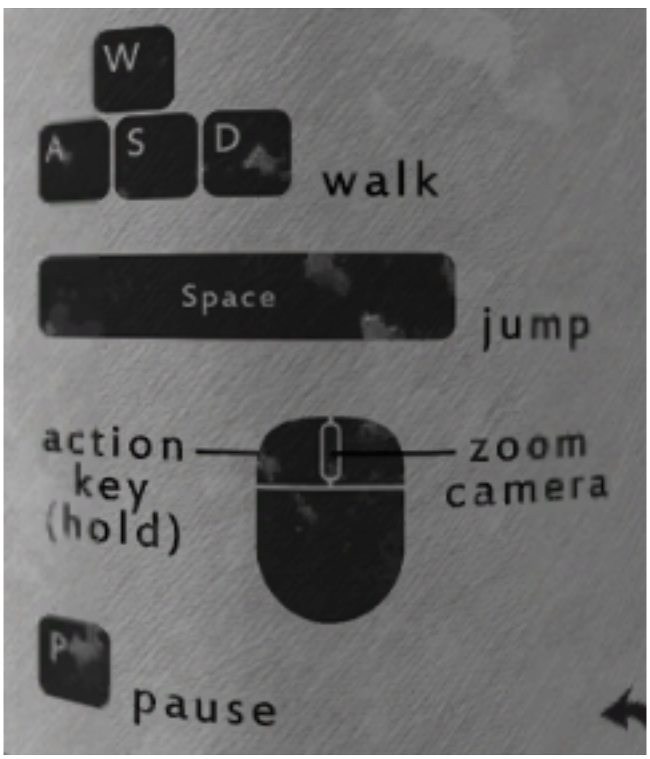

Figure 12 Control menu from *Cantrip* videogame.

Sending signals through a User Datagram Protocol (UDP) Ethernet connection to the computer recording EEG will be used in order to achieve synchronization. Once the test participant has triggered an invisible collider, the mapping of the controls will be changed to a different scheme without warning. This new control configuration will last for 3 seconds before returning to the standard controls. There will be 15 trigger colliders spread throughout the game. The control schemes will be programmed to:

- Last 3 seconds before reverting to normal controls.
- If the test participant is currently manipulating one the control keys during breach of a trigger collider, the randomization will be immediate and also apply to the specific key that is being manipulated.
- In order to compensate for the possibility that a key continuously pressed during the initiation of the triggered randomization is immediately released simultaneously, UDP triggers will be sent both during the initiation of the randomization *and* during the first subsequent key press thereafter.

Furthermore all test subjects will be Video monitored.

Each of the 15 triggers have 4 different states of interest which are recorded and can be analyzed along side the EEG data recorded from the test participants.
1. On entry. (Incongruent onset)
2. On first button press. (Incongruent establishment)
3. On restoration of normal controls (after 3 seconds).
4. On first button press after normal control restore.

These 4 states are important to obtain because, a test participant can:

A. Run into the trigger box while holding a button, therefore changing the interaction of that button immediately.
B. Attempt to adjust (or confirm) their interaction, thereby attempting to manipulate the same, or another, button again.
C. Be holding a button during restoration of normal control (after 3 sec).
D. Attempt to adjust (or confirm) their interaction.

The invisible trigger boxes will be spread throughout the game, leaving space for the test participant to experience the normal control scheme for the majority of gameplay.
The incongruent control schemes will have 15 predetermined variations. Each new invisible trigger box the test participant runs into will result in new, different interactive controls, for 3 seconds.

The task given to the test participants will be to beat the game.

This is in order to see if interaction can elicit N400 during gameplay of a stylistically and visually persistent game experience.
If N400 is recorded, it is of interest to analyze at which point (1, 2, 3, or 4) is most prevalent (if any).

4.2.1.2 Group B

In group B, the test participants will be asked to play the game. Their task will be to beat the game. The control scheme throughout the game will remain the same. The trigger points will also remain the same but not change the control scheme. The primary function of group B is to function as a control group for group A.

The game will have several triggers at points considered Points of Comparison (POC). These points will be located at areas of the game that are considered turning points in the game in both group A and B. The first point, is when the cut scene is triggered and the boy becomes cursed by the witch. The following four are when the player reaches a particular puzzle area. The sixth is when the player comes to a location where they must decide which path to take. These triggers will be recorded but have no effect on the controls of the game.

1. When the player activates the Witch cut-scene.
2. Presentation of first switch puzzle.
3. Presentation of first heavy-magnetism puzzle.
4. Presentation of scrap pile climbing puzzle area.
5. Presentation of second heavy-magnetism puzzle.
6. Presentation of fork in the road choice area.

4.2.2 Procedure

For this test G.Tec EEG recording equipment provided by Aalborg University Copenhagen will be taken into use.
The test participants will be given a questionnaire that is meant to determine their prior knowledge of 3rd person 3D video games, and background questions before they start the test (Appendix 8.5).
The test participants will be placed in front of a screen with mouse and keyboard and put on the EEG sensor hood. The test conductor then injects the conductive gel into the sensors in order to establish connection between the sensor and the scalp of the participant. The signal is then studied to ensure that a connection from the scalp to all sensors has been established.
The test participant will be asked to refrain from any exertive movements while the EEG sensors are recording. This includes strong reactions to the game, such as vocal and physical responses to in-game actions.

The task that the test participants will be asked to complete will be to beat the game.

The test participants will be made aware that:

- The EEG sensors only record data and do not influence the game.
- The game is a puzzle game, where you use the mouse and keyboard as controls.
- The test conductor will interrupt them when they have completed the test.

During the test, a camera will record the actions of the test participant. The camera will view both the screen, keyboard and mouse simultaneously. This is in order to have reference material to review in-game actions along with physical responses that may effect the EEG recordings.
Furthermore, during the test the test participant will be isolated within cubicle walls in order not to be distracted from the game. The test conductor will observe the test participant's actions throughout gameplay.
If the test participant does not understand an aspect of the game and asks for help, the conductor will speak to the test participant from behind, giving them hints as to how to progress throughout the game if needed. These hints must be few and far in between in order for the majority of the test participant's focus to remain on the gameplay.

Once the test participant has progressed throughout the game far enough to travel through all the triggers within the game, the conductor will turn off the EEG recording and interrupt the test and the participant. The participant will then be asked to fill out the post-game potion of the questionnaire (appendix 9.5). Hereafter the EEG hood will be removed and the participant will be offered a paper towel in order to remove the gel from their hair.

5. Implementation

5.1 EEG Equipment

For this experiment EEG recording equipment from G.Tec will be used. This includes proprietary recording and analytical software, electrodes, sensor hood USB amplifier and g.GammaBox which is the electrode driver box for up to 16 electrodes. After applying the electrodes to the correct locations on the hood, the electrodes are then connected to the driver box, which, in turn is connected to the USB amplifier. The amplifier is then connected to a PC via USB running the recording software.

Electrode placement for this test will include 8 electrode locations Fz, Cz, P3, Pz, P4, F3, Oz, F4.
Channel 1 – Fz
Channel 2 – Cz
Channel 3 – P3
Channel 4 – Pz
Channel 5 – P4
Channel 6 – F3
Channel 7 – Oz
Channel 8 – F4
Ground – Yellow
Reference – Blue

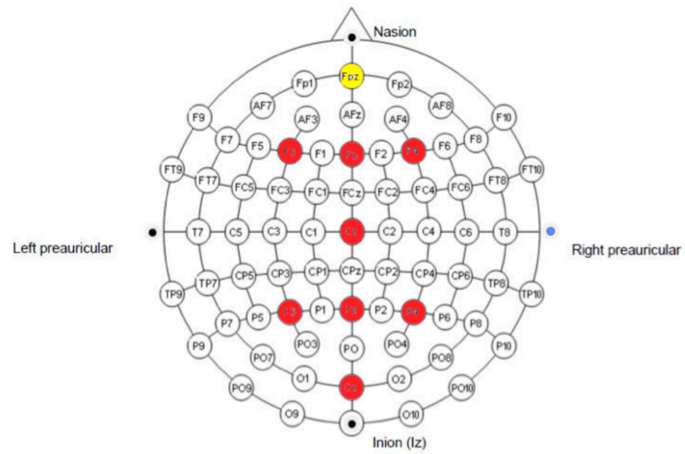

Figure 13 Illustration of electrode sensor placement.

These locations include three electrodes on the frontal lobe, three on the perennial lobe and one sensor on the occipital lobe. These locations seem viable due to suggestions from literature expressing these areas as areas where N400 is more prevalent [19], [24], [25]. Where the frontal lobe is associated with semantic processing, the occipital lobe with visual senses and perennial lobe with spatial senses.

5.2 Implementation of UDP in Cantrip and Stimulink software

In order to implement the necessary triggers mentioned in the design section, trigger objects are constructed and placed throughout the game. Each trigger must be placed along the path the player must travel in order to progress through the game. Using the Unity 3D game engine the project is opened and a rectangular object is created and labeled as a trigger. Since there is no texture or mesh assigned to this object it will be invisible during gameplay. It is labeled *trigger* so that it will not be affected by in-game physics and the player will be able to travel through them unaware of their presence.
Upon entering one of the *trigger* objects, the player will experience that the control scheme they have become accustomed to will be changed. Implementing a script that recognizes when the player has activated (walked into) the *trigger* [appendix 9.3] sends the data to the computer recording the EEG data. The script that is placed on the *trigger* is doing two things, first it is changing the control scheme to a control scheme specified in the *Project Settings*, under *Input.* 15 different control schemes have been implemented and each trigger changes to a different scheme [appendix 9.4].

Once the trigger has been activated, the trigger itself is destroyed, so that it cannot be activated again. After 3 seconds the control scheme changes back to "0" which is the standard control scheme. The second function is to send data via UDP to the computer recording the EEG signals from the electrode sensor hood. Creating a network between the host computer and the recording computer was necessary.

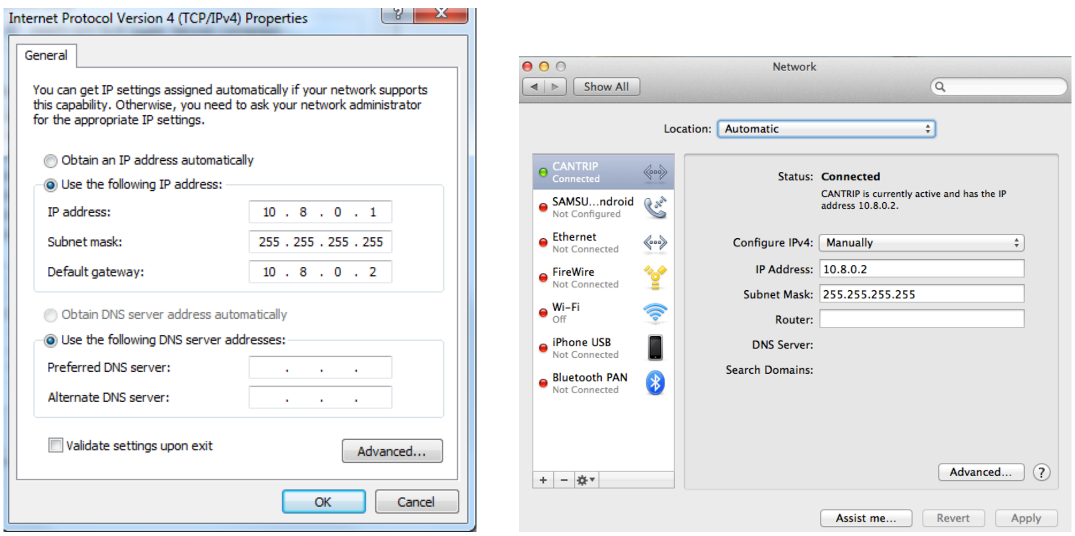

Figure 14 . Network settings on EEG recording computer (left) and game host computer (right).

This allowed for the UDP signals to be recognized through the network.

In order to receive the UDP data from the game host computer, it was necessary to construct a Simulink model that receives the EEG signals from the USB amplifier and simultaneously the data coming from the gameplay via UDP.

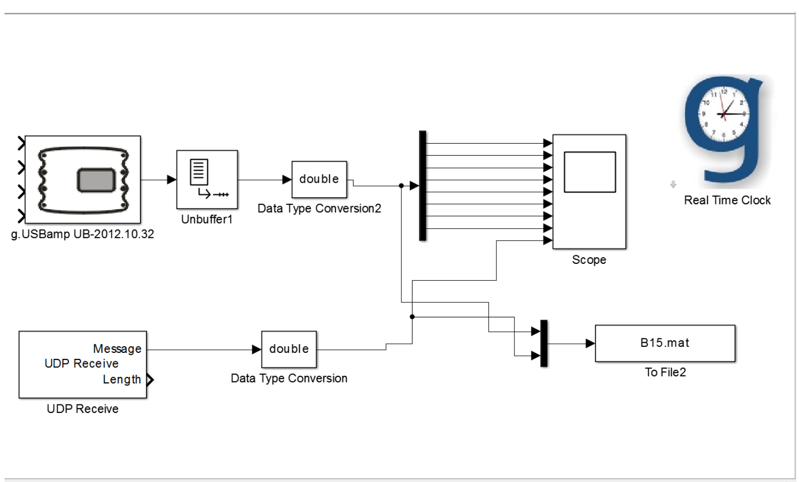

Figure 15 Stimulink Model used for USBamp & UDP recording.

This model receives data from the USB amplifier and the UDP signals originating from the computer the test subject is using to play the game. The USBamp module was set up to receive EEG recordings at 256 samples per second (Hz). The UDP Receive module was set up to receive incoming packet from the IP address of the game-host computer at the same port the game is sending from (port 8000).

The data recorded is saved in the ToFile module as an array with a sample time of 1/256. This array has 10 rows, 1 for time, 8 electrode sensor data and 1 for trigger data.
The Real Time clock within the Stimulink model added one row of real-time. Thereafter there are 8 rows of data in the array, from the 8 electrode sensors. Finally there is the 10th row, which is where the trigger data has been stored. The script that sends the data from the game to the data-recording computer signifies each trigger and its four states accordingly. In order to make sure that the signal would be constant, the script sends the trigger data as integers. For example, the first trigger would change the value of the 10th row to '1001' upon trigger enter within the game, thereafter when the player presses another button input, the trigger value will be changed to '1002'. The first number indicates the trigger number, while the last number indicates the state within that trigger (1, 2, 3 or 4).

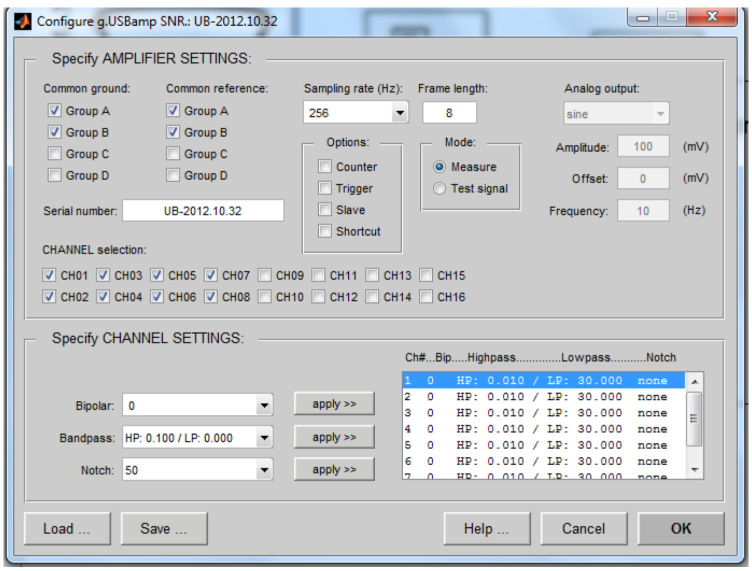

Figure 16 USBamp module settings. Notice the band pass setting has been applied to all 8 channels.

The locations of the triggers within the game are spread out in order to ensure that the test participant has time to get used to the standard control scheme that the game offers. There are 15 triggers over 2 levels of the game. The intent is to have each player continue to progress throughout the game until they have hit all 15 triggers.

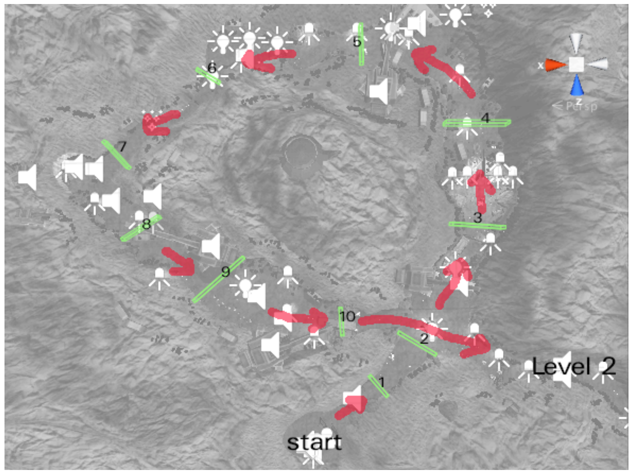

Figure 17 Topographical level view. Trigger locations in level 1 (green). Arrows indicate the path of progression throughout the level for the player (red).

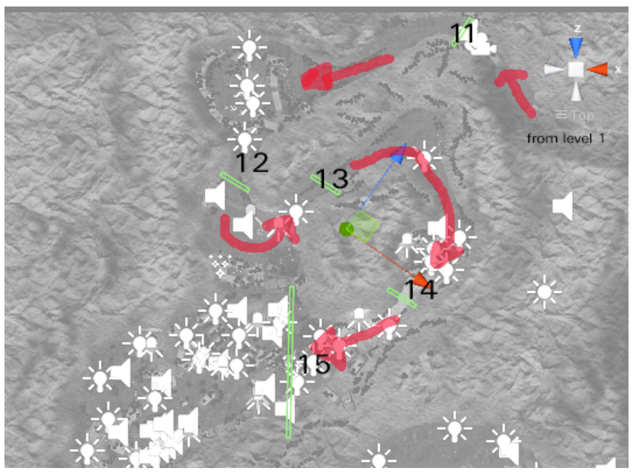

Figure 18 Topographical level view. Trigger locations in level 2 (green). Arrows indicate the path of progression throughout the level for the player (red).

6 POC are implemented within the game. These are sphere triggers at different points. Their goal is to have areas of interest within the EEG data that can be compared over all subjects, both those in groups A and B. Their placement was chosen at certain crucial points within the game.

7. When the player activates the Witch cut-scene.
8. Presentation of first switch puzzle.
9. Presentation of first heavy-magnetism puzzle.
10. Presentation of scrap pile climbing puzzle area.
11. Presentation of second heavy-magnetism puzzle.
12. Presentation of fork in the road choice area.

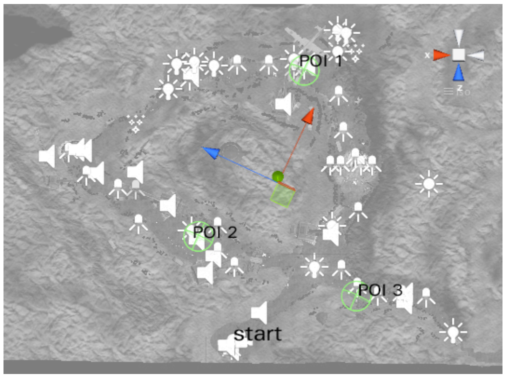

Figure 19 POI in level 1.

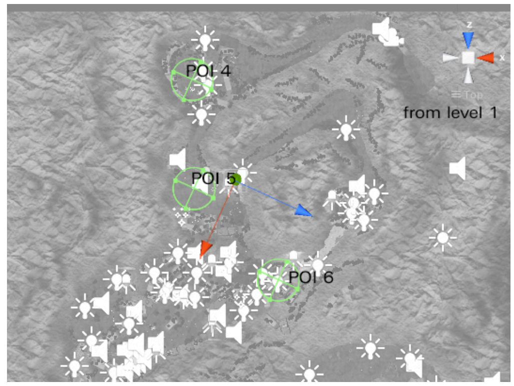

Figure 18 POI in level 2.

These POC points are chosen in order to attempt to account for similarities in EEG readings at a narrative driven point (POC 1) and points where the test subject must assess their environment within the game in order to progress.

Figure 20 Photo of test setup in use.

A GoPro camera is being used to record each test subject. Because of the camera's wide-angle lens it can capture both what is happening on-screen as well as the keyboard strokes made by the test participant. This video footage will not be synched with the EEG data. Though it may be useful reference for potential EEG anomalies encountered while analyzing the data.

6. Results

The test was completed with 15 participants in both groups A and B. Each participant filled out both pre- and post-game questionnaires. Each test took about 15 to 40 minutes to complete depending on setup time and time it took the participant to complete the task.
The test participants were 25 male and 5 Female.
Group A (13 male, 2 female) Group B (12 male, 3 female) ages varied from 22 to 42 years of age with a mean age of 27 (7 participants).
1 out of 30 test participants were left handed (A15). This participant was also the only one who had not previously experienced a 3rd person videogame.

6.1 Analysis of EEG data

Each test participant resulted in a dataset composed of 10 rows and thousands of columns. The trigger data on row 10 had to be analyzed in order to pin point the exact onset of the incongruent interactive change.

GBSAnalyze is a computer program from G.Tec that allows for loading EEG data and visualizing it in different ways. For the sake of this experiment we are interested in finding the 4 states along all 15 triggers. Each trigger has 4 states.

GBSanalyze is able to “trigger” a dataset that is loaded into the software. This triggering of the data set lets the user specify which channel is the “trigger” channel and which parts of the dataset around the trigger are of interest.

By “triggering” the dataset for a specific test participant, one is able to analyze a small, specified area around the trigger location on the trigger channel. Since this experiment uses 15 triggers and 6 points of comparison, each with 4 points of interest, there are 84 triggers per test participant that must be analyzed.

In order to do this a Matlab script was written (appendix 9.7.1) in order to split the dataset into 8 datasets. The first four files were states 1, 2, 3 and 4 for the 15 triggers. The last four files were states 1, 2, 3 and 4 for the POC triggers.
Each of the 8 files have replaced the all of the data along the triggering row with zeros, except for onset of the trigger for the file’s specified state.
This means that for each test participant there are 8 files, each triggered only at the points corresponding to a specific state.
This allows for each file to be loaded into g.BSanalyze for analysis.

We are interested in the following:

a. Detect the presence of N400 (or other) ERP after incongruent interaction has been experienced.

b. Which point of interest was most likely to elicit the N400 (or other) ERPs.

To begin, the N400 ERP can be found around 400ms after the stimuli (trigger), and it has been suggested that it may deviate slightly from 200ms before to 900ms after stimulus [23]. The area of interest for this experiment has been chosen to be ca. 100ms before and 700ms after the trigger point. This is in order to estimate if an affect has occurred around 400ms and also provide a more detailed visual description of the data after stimulus onset.

Once the dataset has been divided and labeled by the script, g.BSanalyze is used to find each trigger state and cut out the -100ms and 700ms window around the trigger state.

Once this script has been applied to all of the 30 test participant recordings, each of the 8 files must be loaded into g.BSanalyze and “triggered”.

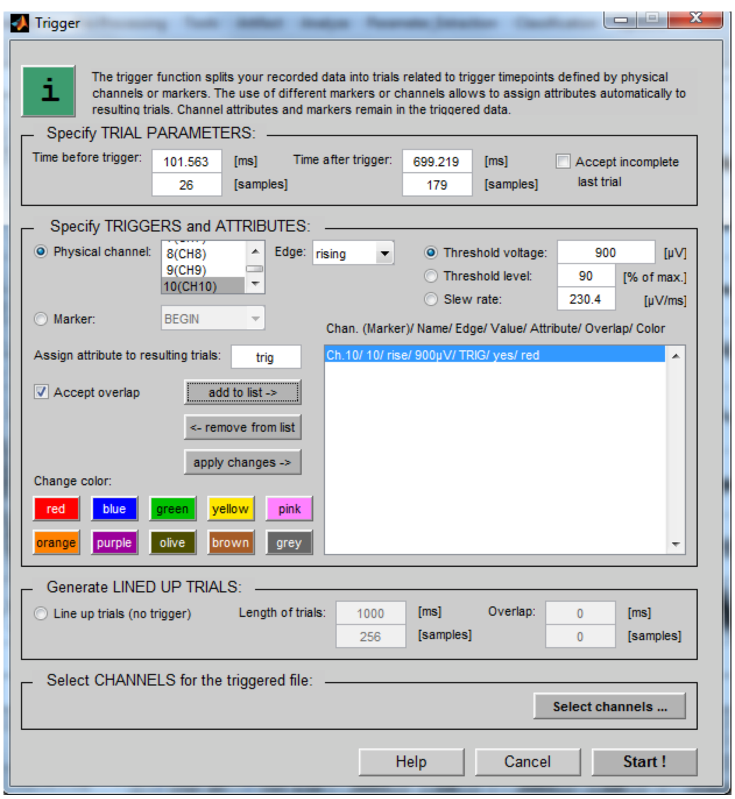

Figure 21 Trigger menu for g.BSanalyze. Here the parameters are set for ca. 100ms before and 700ms after trigger onset. The trigger channel is specified to channel 10.

After triggering has occurred the g.BSanalyze software has found all triggers within the file, cut them into 800ms windows and deleted all other information. This results in a dataset with 15 x 800ms segments.

Hereafter the dataset is then averaged. This is done by using the averaging tool in g.BSanalyze that computes the simple average of the 15 triggered segments and displays them by individual channel. In this case the channels are from 2 to 9. This is because channel 1 (time) and channel 10 (trigger channel) have been left out of the averaging process.

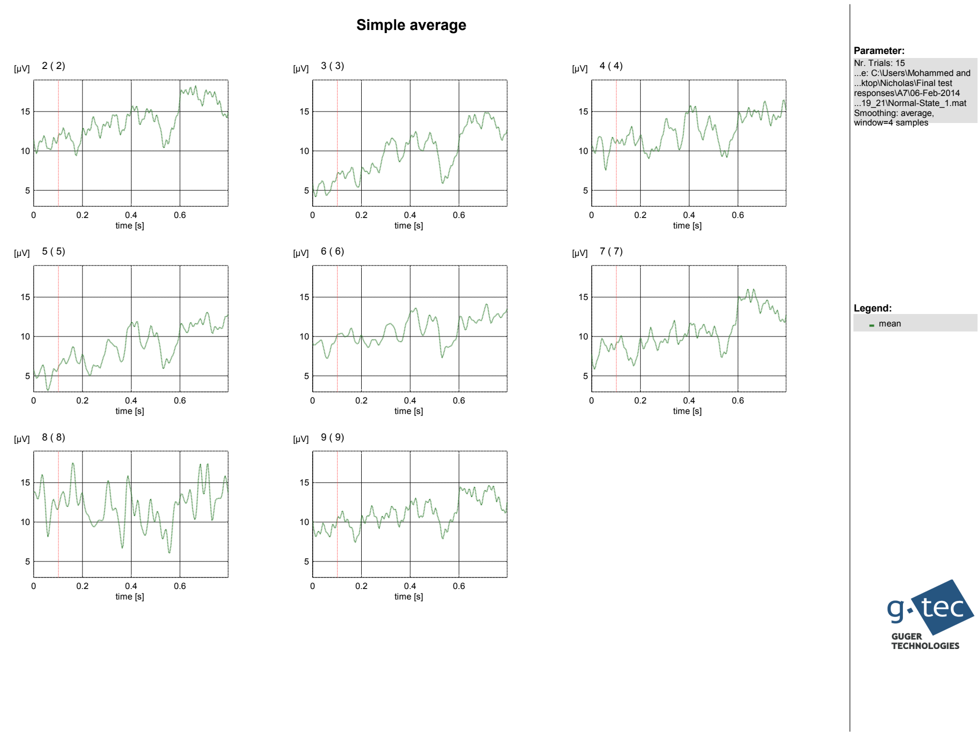

Figure 22 Averaged result for trigger x001 for participant group A number 7.

In the figure above (figure 22) is the final result for a particular set of triggers. These results were produced for all 240 files produced, 8 files for each of the 30 participants. The 240 result PDF files are featured on the DVD that accompanies this document.

6.1.1 Analysis and reiteration

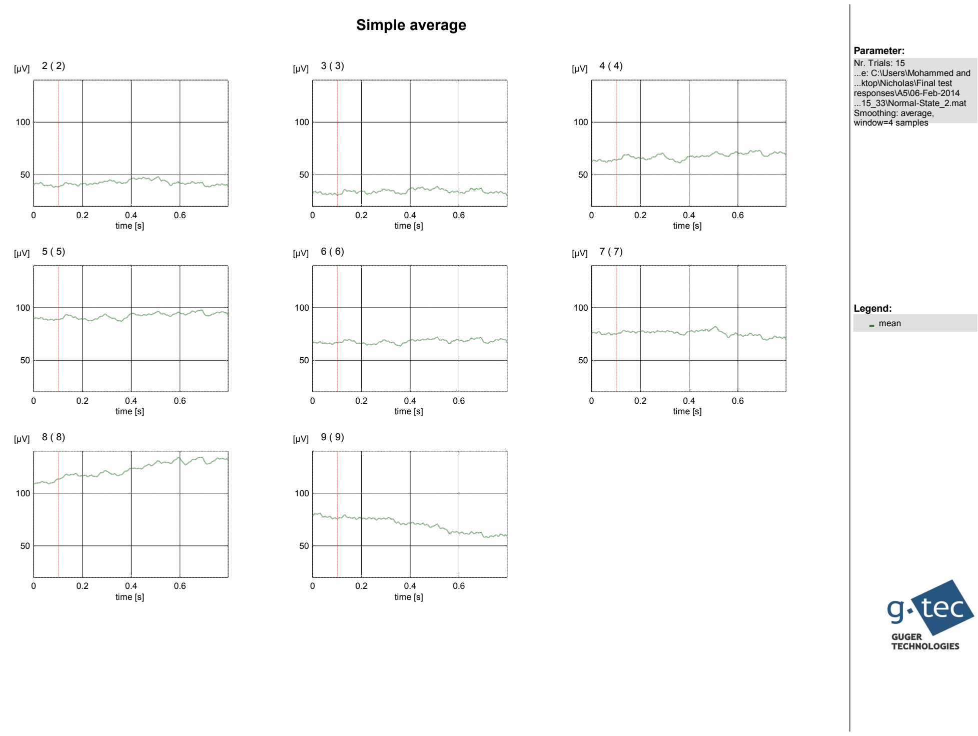

Figure 23 Averaged result for A5 x002 for all 15 triggers. Here it can be seen that the y-axis represents a span of 150 microvolts.

After close analysis of the generated results, the 5 test participants (A15, A2, A5, A9 and A14) in group *A*, among others, show very flat signal readings. This is due to the microvolt scale featured on the y-axis of the chart. Some of the charts feature microvolt levels ranging over 100 microvolts (see figure 23), while others (see figure 22) range only 20 microvolts. The x-axis shows always a constant time frame of 800ms. This results in some of the charts lacking a considerable level of detail, especially when the artifact in question (N400) usually is denoted by an offset of ca. 10 microvolts.

In order to reiterate this data, EEGLab software was used in order to apply a new band pass filter to each data set. The band pass filter range was from 1hz to 30hz. All frequencies above 30Hz and below 1Hz are attenuated from the file. The new filtered datasets show a much more stable range in microvolt when averaged. This is however puzzling due to the fact that a band pass filter was already applied in the USBamp settings during recording (see figure 14). However, this previous band pass filter, applied to the USBamp was from a range of 0.01Hz to 30Hz. This means that the frequencies found between 0.01Hz and 1Hz may account for the differences.

Applying another band pass filter does affect the accuracy of the readings since sources suggest not applying digital filtering prior to quantification of ERPs [23].

Despite these considerations potential artifacts are present when visualizing these new filtered averages (appendix 9.1). It was observed that the majority of test participants were holding down a button when activating a trigger, this causes both the first signal (x001) to be sent and the second signal (x002) to be sent 1/256th of a second later. The trigger state x002 was chosen to display in the appendix because it is the most likely state at which the test participant noticed the change in control scheme. Trigger state x002 also showed the most prevalent tendencies to N400 ERP prior to additional band pass filtering.

A similar band pass applied to group B participants 1-15 on the x002 state reveals many anomalies as well. These are partially due to the smaller variation of microvolt expressed by the y-axis. All averaged files for group B featured in appendix 9.2 have approximately -10 to 10 mircovolt measured on the y-axis. Averaged files for group A have approximately -20 to 20 microvolt measured on the y-axis.
The Result2D software was unable to be adjusted to an equal scale for all measurements, which would have allowed for optimal viewing and assessment.

6.2 Qualitative analysis

When asked to describe in their own words the story of the game, all participants were able to explain the narrative, either referencing its resemblance to the known German folk tale *Hansel and Gretel,* or paraphrasing some of the monolog heard by the narrator of the game. There was no discernable difference between group A and B when describing the story of the game. The control scheme changes in the version of the game played by group A did not influence their understanding of the narrative.

Five of the test participants in group A (A4, A6, A7, A8, A14) mention specifically that the controls were a challenge throughout gameplay. One participant (A13) claims that instability was a challenge. Other aspects of the game that test participants found challenging were similar across both groups (appendix 9.6).

All test participants described the magnetism game mechanic as the primary ability of the character they played in the game. Some test participants mentioned movement (B1, B2, A3, A4, B5, B10, B11, A13, B15).
When asked if there were any areas within the game that the test participant found challenging, most stated the areas where a puzzled must be solved in order to progress. B14 mentioned that the controls were challenging due to their sensitivity.

Group A found the game experience both more awkward and less smooth than that of group B.

	Awkward	Smooth
Group A average	3.06 (stdev 1.2)	2.8 (stdev 0.7)
Group B average	2.06 (stdev 0.96)	3.53 (stdev 0.9)

This shows a tendency that group A may have been affected by the 15 instances of control scheme change to such an extent that it influenced the judgment of their overall experience.

6.3 Conclusion of results

After applying a band pass filter to the second state of all triggers for group A and averaging them individually by test subject, robust examples of the N400 can be found in A1, A3, A6, A7, A10 and A12. The other averages within group A exhibit trends but are not as clear depictions of the event related potential.
A13, A7 and B1 answered *yes* to taking medicine that influences the central nervous system, therefore their results should be taken into consideration as invalid.
The questionnaire also made it clear that test participants in group A were aware of the changes in control scheme throughout gameplay.

6.4 Discussion

There are many different ways that the test could have been improved upon. It would have been interesting to add more electrodes to the hood during testing. With further analysis, one could analyze the exact locations of N400 and specify if interactive incongruence deviates from the standard areas of the scalp where N400 is prevalent in other tests.
This would not only help with pinpointing the location of N400 within the brain, but also perhaps provide insight to practical applications of the ERP, either in regard to user testing or automated feedback.

The test should have included a front facing camera in order to record facial expressions during gameplay. This may also have been useful in determining eye blinks and other muscular exertions that may have influenced the EEG recordings. The large deviation in voltage amplitude for many of the results could have been affiliated with muscle noise. Further testing is needed to evaluate the extent of muscle noise (fx. with keyboard and mouse hand movement) in order to determine the best practices when attenuating it from datasets.
Besides N400 there are many other EEG modalities that may be applied to

interactive systems, such as steady state evoked potential. It would be of interest to pursue which are best suited for these purposes.

The post questionnaire should have included questions pertaining to if the test participant believed they had been influenced by the game to be vocal or been provoked to physically move their bodies in ways not crucial to game interaction.

Observation bias was a concern especially for the test participants who required verbal help from the test conductor in order to progress throughout the game and therefore complete the test.

In retrospect the formation of the POC does not necessarily have to be that of a spherical nature. The reason for their spherical shape was due to the sphere trigger that initiates the first POC, namely the Witch cut scene. The remaining POC triggers have the same shape as this trigger. The spherical shape allows for the player to walk into the trigger earlier from the center than from the sides. Although this is a minute discrepancy, it is a design choice that should be reevaluated in future tests; the positioning and form of the active trigger elements.

7. Conclusion

Good examples of the N400 ERP were found in several of the end results (see appendix 9.1 fig. 22, 24, 27, 31, 33). These results represent an average done on each test participant at the 2nd state of each trigger. Each test participant was exposed to 15 cases of incongruent interactive stimuli.
Inexperienced individuals were outliers of the experiment. The majority of the test subjects had tried playing similar videogames with similar controls before (appendix 9.6). The average experience with 3rd person videogames was 2.26 (stdev0.79) for both test groups.
The POC points of comparison did not reveal any artifacts of interest. This is due to their large spread over micro-voltage potential on varying electrode locations. The averages gathered from these points vary widely and seem subjective (see result pdfs on dvd).

The N400 ERP within interactive incongruence indicates that narrative coherence also encompasses disruptions in the communication of interactive capability. These interactive signaling processes are also bound to the narrative aspects of the experience. The N400 ERP has been established through semantic incongruence and now to an extent, incongruence in automated control. A sense of control is one of the 8 criteria of flow. These results show tendencies that deviating from that criterion elicits the same cognitive reaction as other incongruent stimuli.

8. References

[1] Winters, Tara, 2005. Evaluating digital, interactive multimedia experiences. In: IT University of Copenhagen *Proceedings of the 6th Digital Arts & Culture (DAC) 2005 Conference.* Copenhagen, Denmark, 1-3 December 2005. IT University: Copenhagen.

[2] The Narrative Construction of Reality
Jerome Bruner
Critical Inquiry , Vol. 18, No. 1 (Autumn, 1991), pp. 1-21
Published by: The University of Chicago Press
Article Stable URL: http://www.jstor.org/stable/1343711

[3] From Parlor Games to Social Science: Von Neumann, Morgenstern, and the Creation of Game Theory 1928-1944 Author(s): Robert J. Leonard Source: Journal of Economic Literature, Vol. 33, No. 2 (Jun., 1995), pp. 730-761 Published by: American Economic Association Stable URL: http://www.jstor.org/stable/2729025

[4] Craig A. Lindley, 2002. The Gameplay Gestalt, Narrative, and Interactive Storytelling. In: *Proceedings of Computer Games and Digital Cultures Conference*, Visby Sweden, Tampere: Tampere University Press, 2002.

[5] Charlie Hargood, David E. Millard, Mark J. Weal. 2008. A Thematic Approach to Emerging Narrative Structure. *WebScience'08*, June 19, 2008, Pittsburgh, Pennsylvania, USA.

[6] De Saussure, Ferdinand. *Course in general linguistics*. Columbia University Press, 2011.

[7] Short, Thomas Lloyd. *Peirce's theory of signs*. Cambridge: Cambridge University Press, 2007.

[8] Atkin, Albert. Copyright © 2010 <albert.atkin@mq.edu.au>
http://plato.stanford.edu/entries/peirce-semiotics/

[9] Umberto, Eco. *The role of the reader: Explorations in the semiotics of texts*. Vol.

318. Indiana University Press, 1984.

[10] Chen, Jenova. "Flow in games (and everything else)." *Communications of the ACM* 50.4 (2007): 31-34.

[11] Lindley, Craig A. "The Gameplay Gestalt, Narrative, and Interactive Storytelling." *CGDC Conf.*. 2002.

[12] Jenkins, Henry. "Game design as narrative architecture." *Computer* 44 (2004): s3.

[13] Bruni L., Baceviviute S., Author-Audience Distance: The Parameters of Interactive Narratives. (in press) Aalborg University Copenhagen. Copenhagen, Denmark. 2013

[14] Mirza-Babaei, Pejman, et al. "Understanding the contribution of biometrics to games user research." *Proc. DIGRA*. 2011.

[15] p. 172. Magy Seif El-Nasr, Anders Drachen, Alessandro Canossa, "Game Analytics: maximizing the value of player data" Springer-Verlag London 2013

[16] Sims 3 screenshot. Retrieved last: 10/1/14 from: http://joyreactor.com/post/444347

[17] Kutas, M. & Hillyard, S., 1980. Reading Senseless Sentences: brain potentials reflect semantic incongruity. Science, p. 203–205.

[18] Klintfors, E., Marklund, E., Kallioinen, P., & Lacerda, F. (2011). Cortical N400-potentials generated by adults in response to semantic incongruities. In *Proceedings of Fonetik 2011: Speech, Music and Hearing TMH-QPSR Vol. 51* (pp. 121-124). Universitetsserveice AB.

[19] Proverbio, A. M., & Riva, F. (2009). RP and N400 ERP components reflect semantic violations in visual processing of human actions. *Neuroscience letters*, *459*(3), 142-146.

[20] Sitnikova, T., Holcomb, P. J., Kiyonaga, K. A., & Kuperberg, G. R. (2008). Two neurocognitive mechanisms of semantic integration during the comprehension of visual real-world events. *Journal of Cognitive Neuroscience*, *20*(11), 2037-2057.

[21] Oxford English Dictionary "gameplay, n.". OED Online. December 2013. Oxford University Press. 11 February 2014 <http://www.oed.com/view/Entry/319024?redirectedFrom=gameplay&>.

[22] Kivikangas, J. Matias, et al. "Review on psychophysiological methods in game research." *Proc. of 1st Nordic DiGRA* (2010).

[23] Duncan, C. C., Barry, R. J., Connolly, J. F., Fischer, C., Michie, P. T., Näätänen, R., ... & Van Petten, C. (2009). Event-related potentials in clinical research: guidelines for eliciting, recording, and quantifying mismatch negativity, P300, and N400. *Clinical Neurophysiology*, *120*(11), 1883-1908.

[24] James, T. W., Humphrey, G. K., Gati, J. S., Servos, P., Menon, R. S., & Goodale, M. A. (2002). Haptic study of three-dimensional objects activates extrastriate visual areas. *Neuropsychologia*, *40*(10), 1706-1714.

[25] Lau, E. F., Phillips, C., & Poeppel, D. (2008). A cortical network for semantics:(de) constructing the N400. *Nature Reviews Neuroscience*, *9*(12), 920-933.

9. Appendix

9.1 A1-A15 individually averaged across all 15 x002 states.

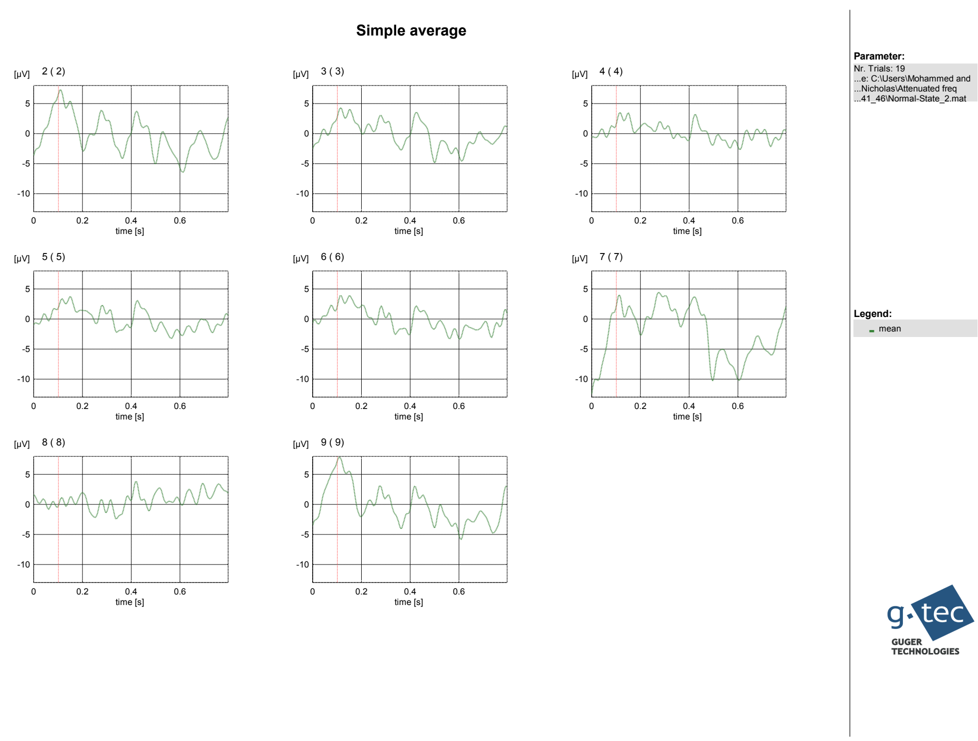

Figure 24 A1 x002 averaged

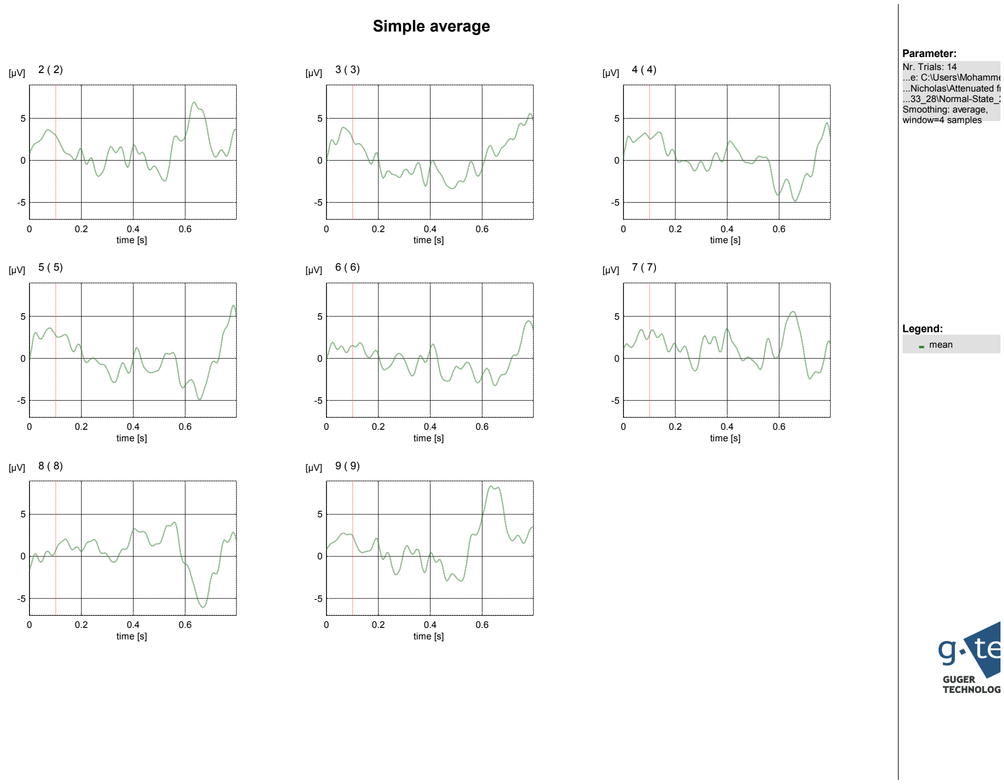

Figure 25 A2 x002 averaged.

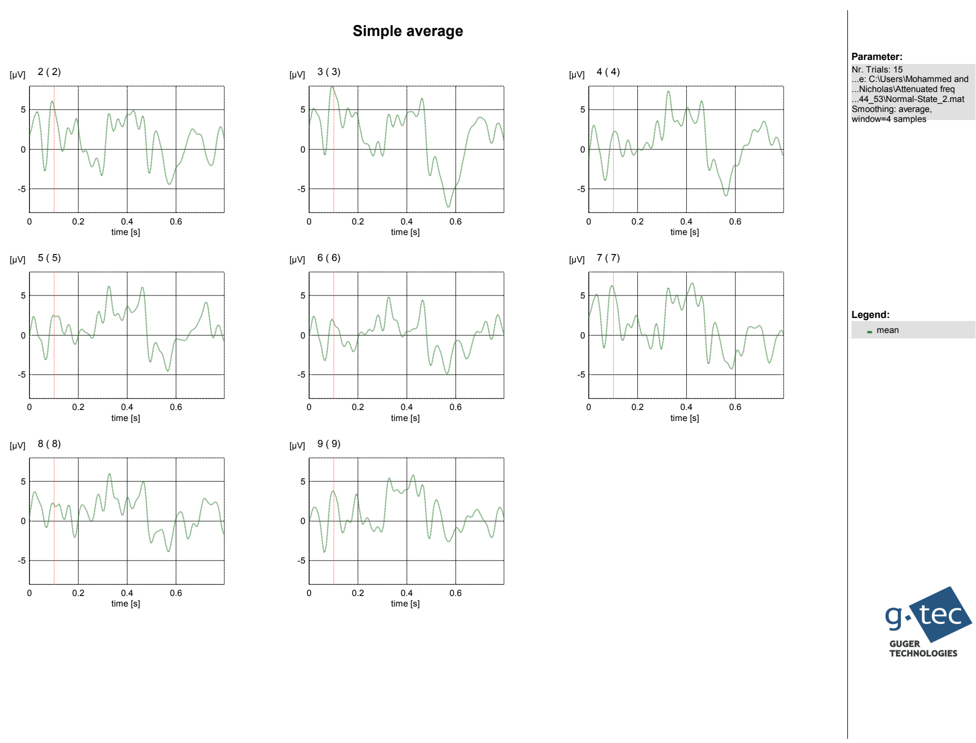

Figure 26 A3 x002 averaged.

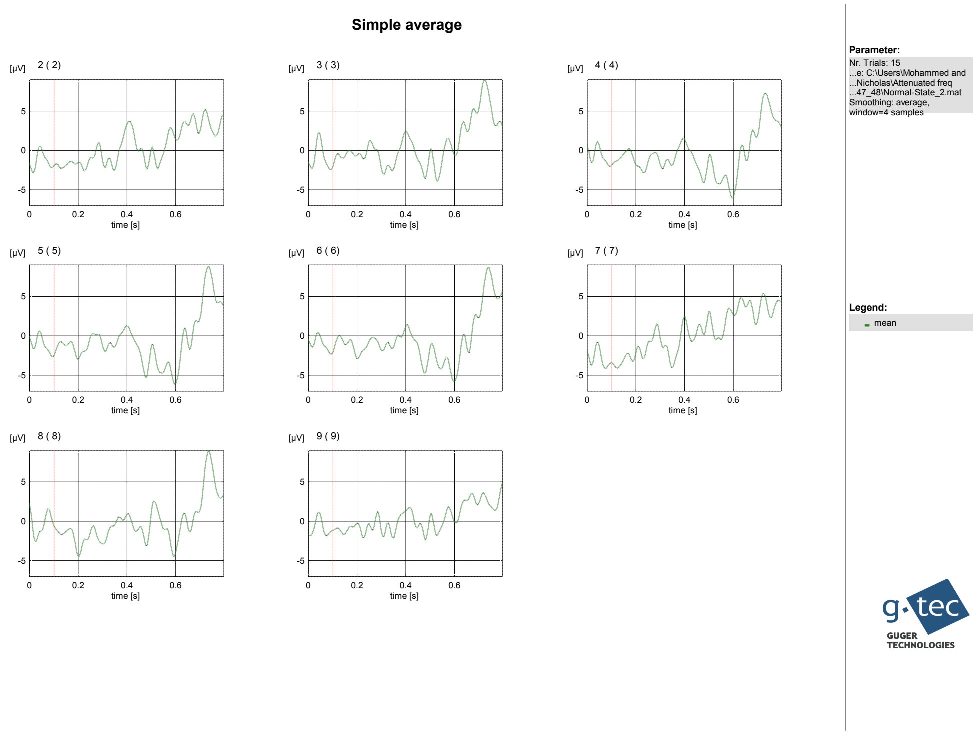

Figure 27 A4 x002 averaged.

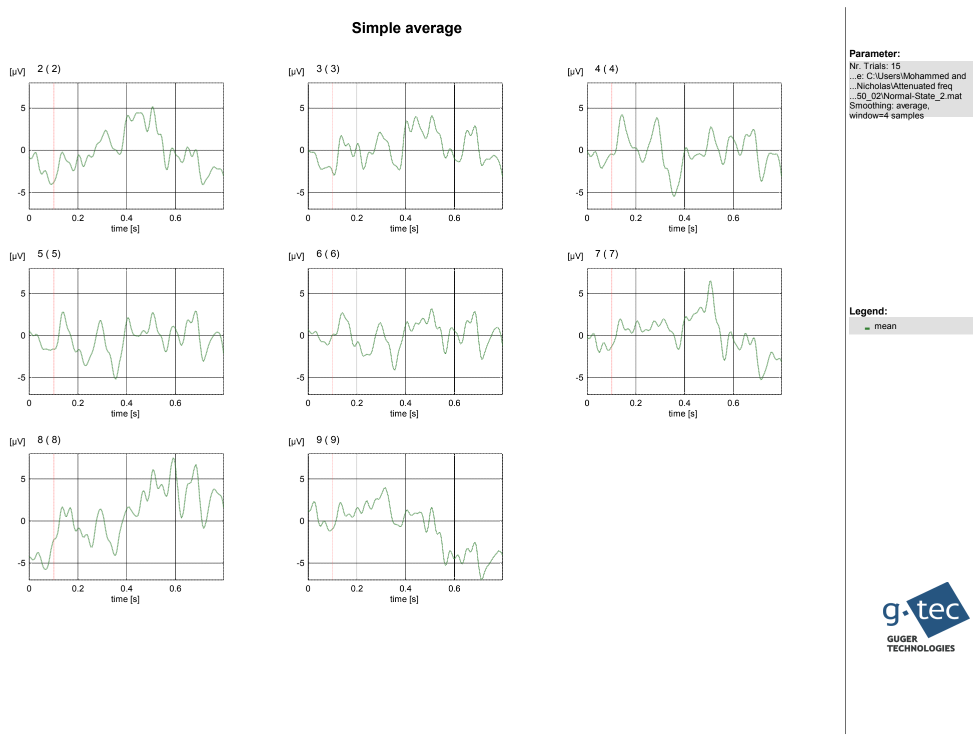

Figure 28 A5 x002 averaged.

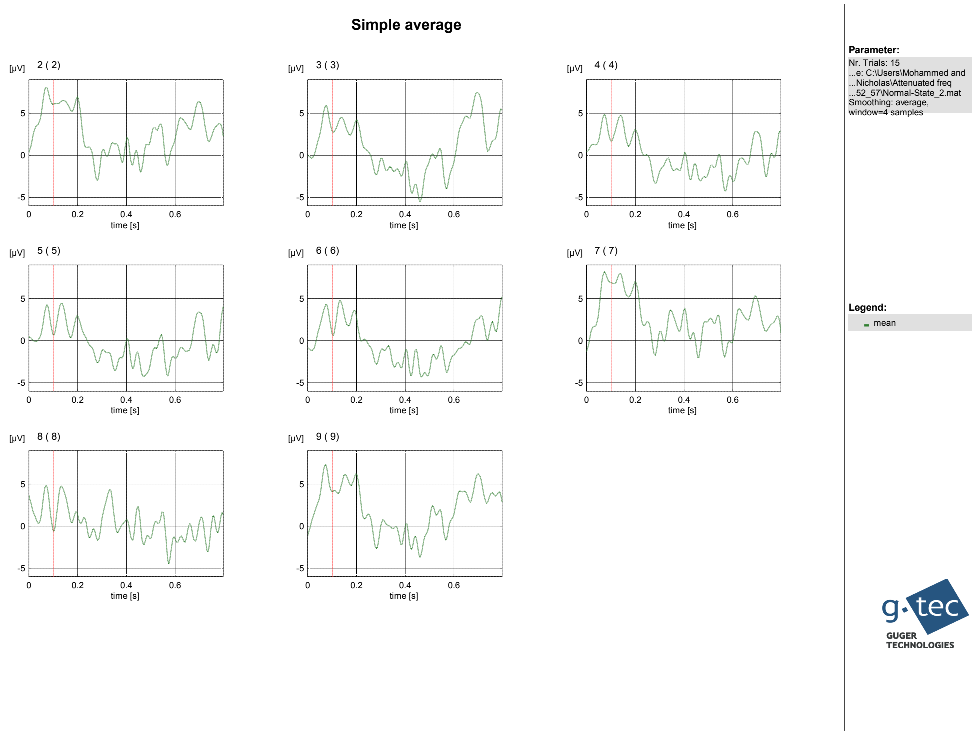

Figure 29 A6 x002 averaged.

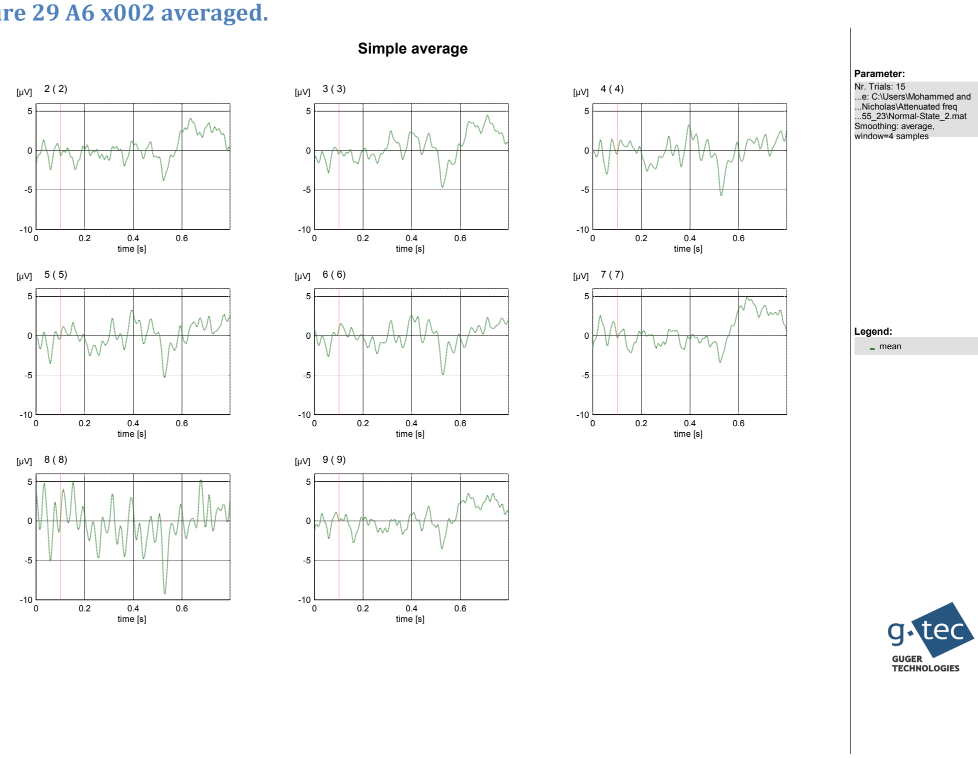

Figure 30 A7 x002 averaged.

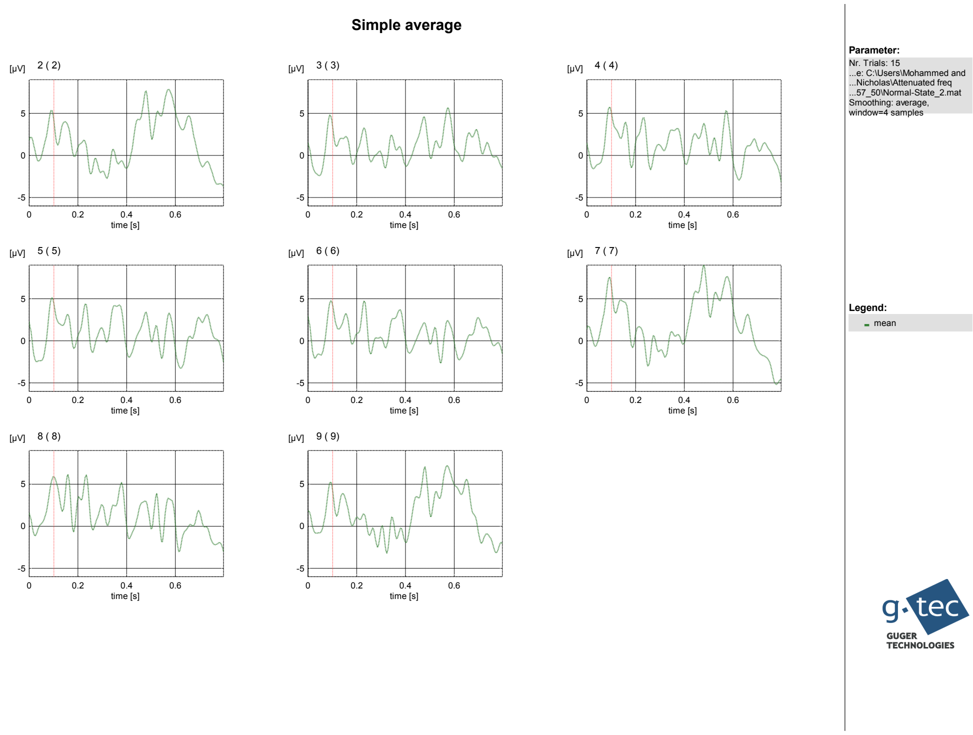

Figure 31 A8 x002 averaged.

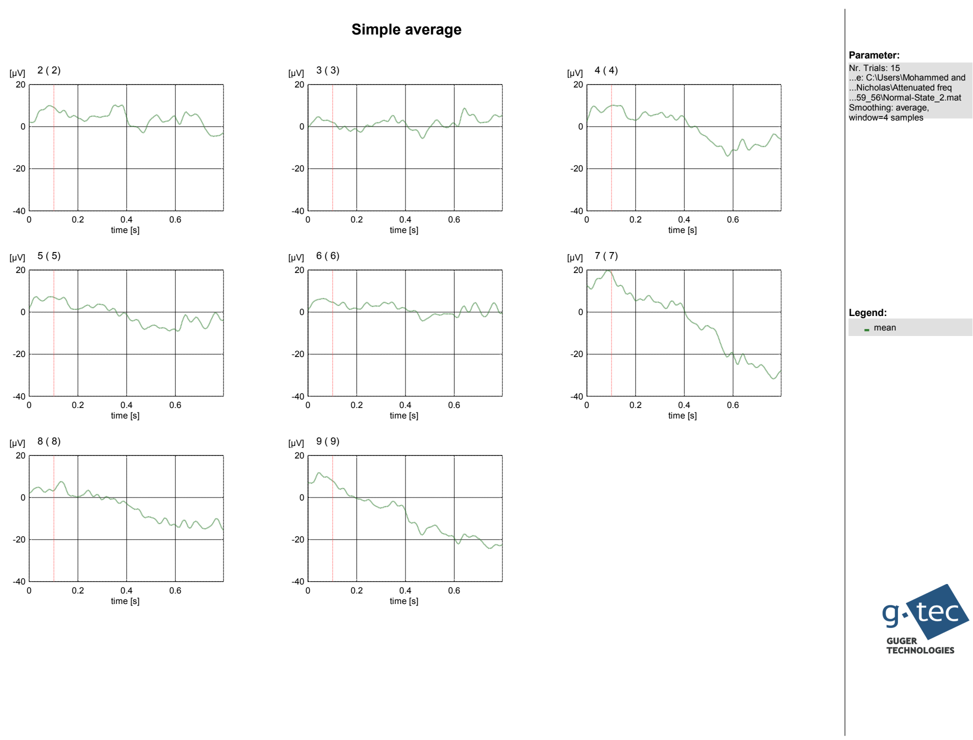

Figure 32 A9 x002 averaged.

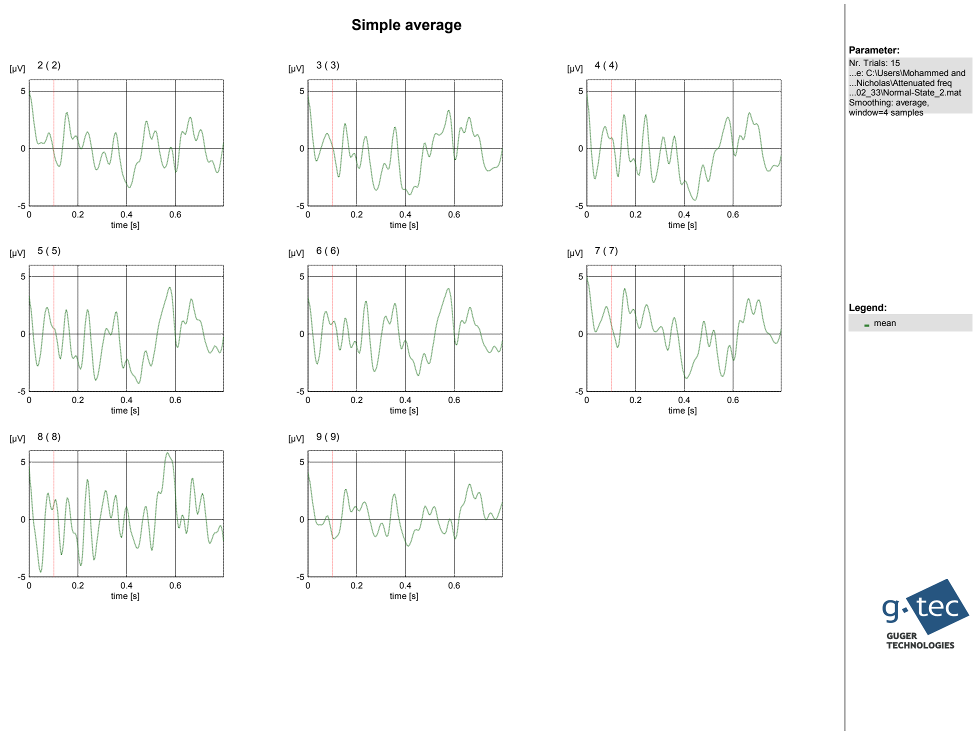

Figure 33 A10 x002 averaged.

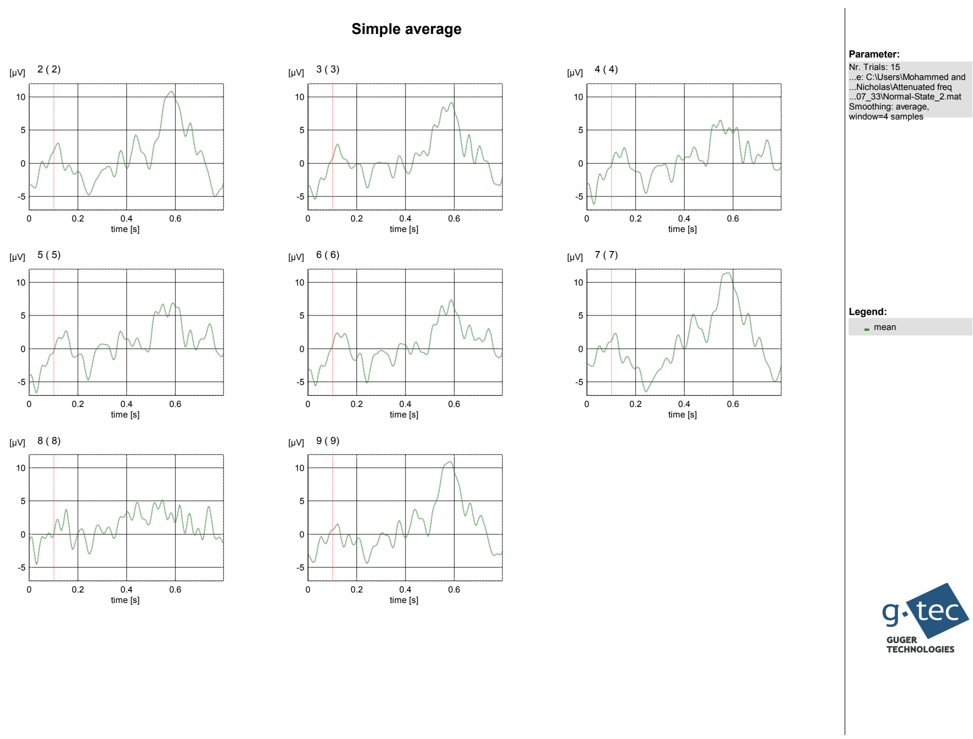

Figure 34 A11 x002 averaged.

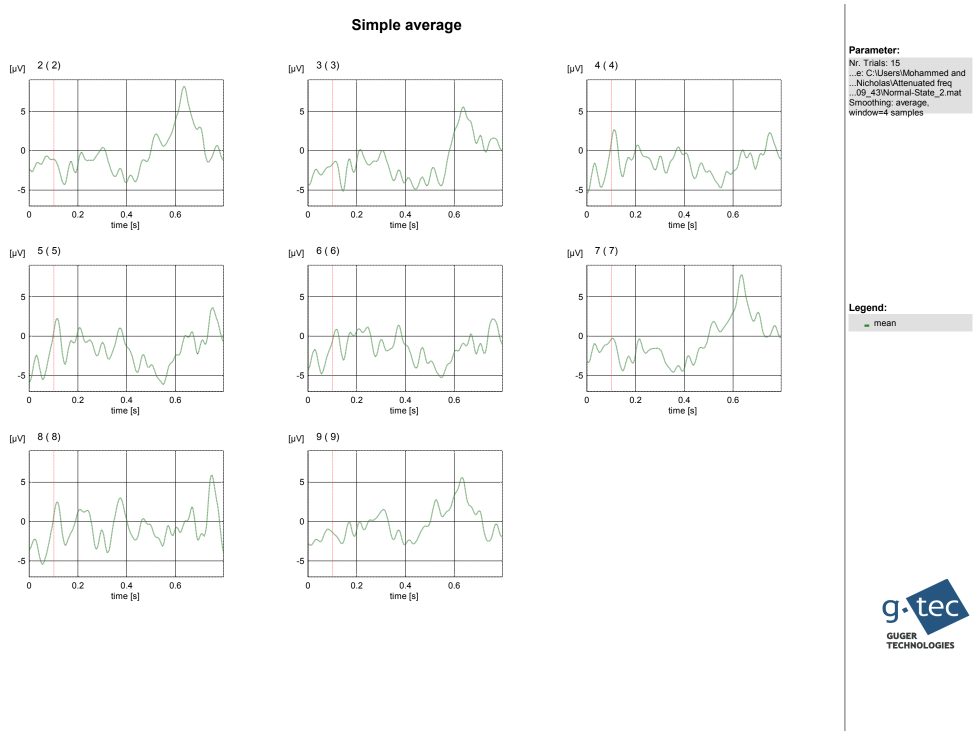

Figure 35 A12 x002 averaged.

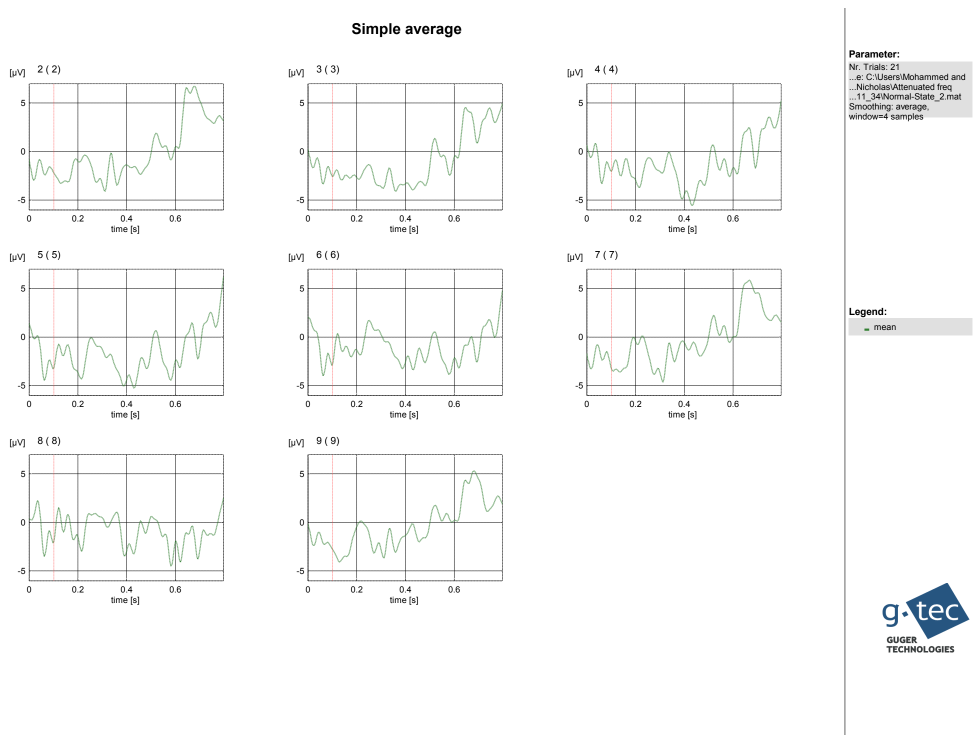

Figure 36 A13 x002 averaged.

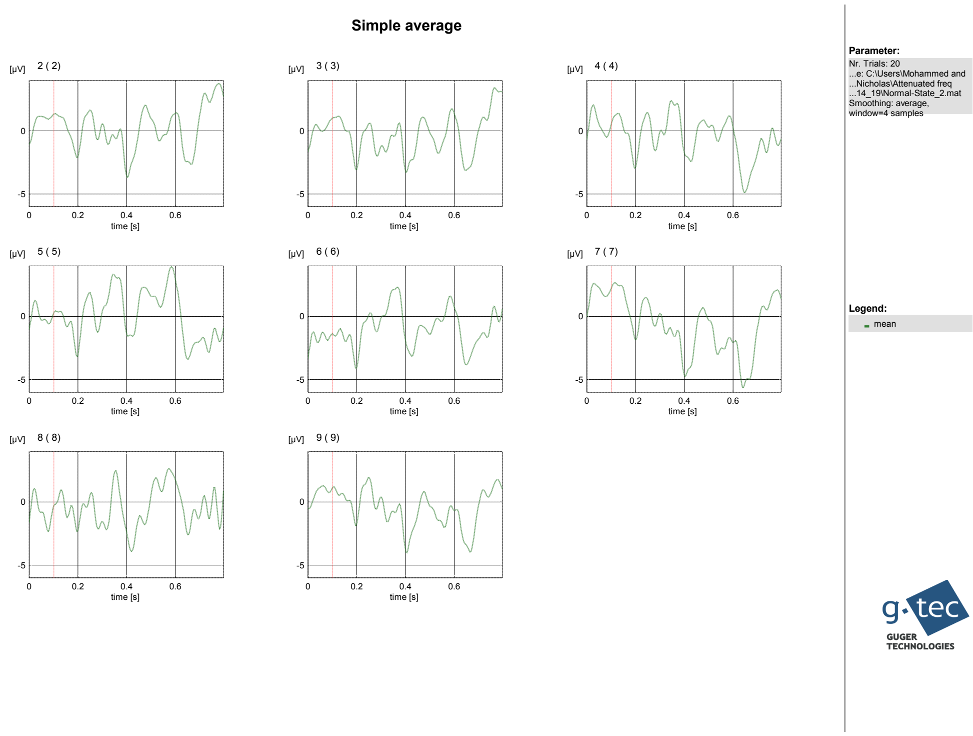

Figure 37 A14 x002 averaged.

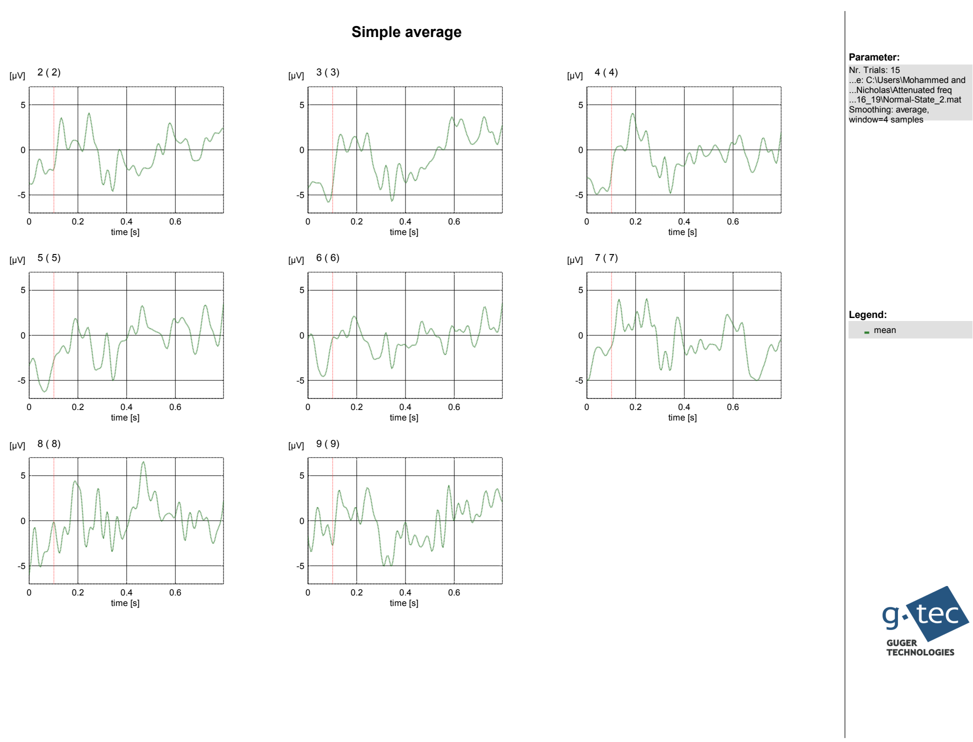

Figure 38 A15 x002 averaged.

9.2 B1 –B15 individually averaged across all 15 x002 states.

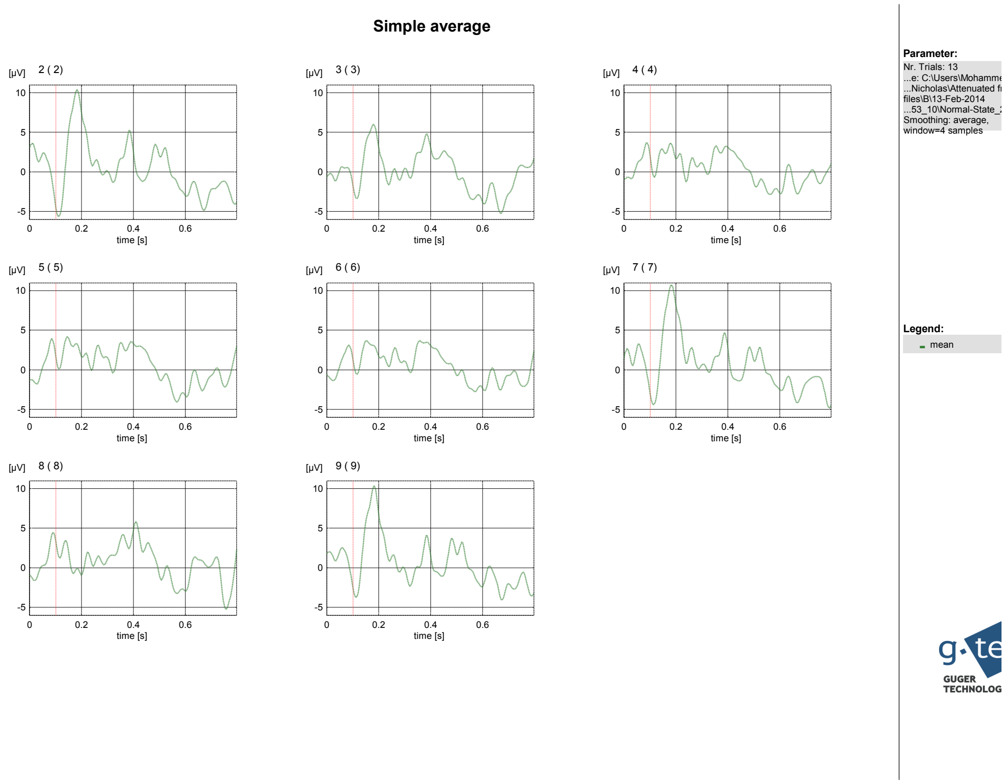

Figure 39 B1 x002 averaged

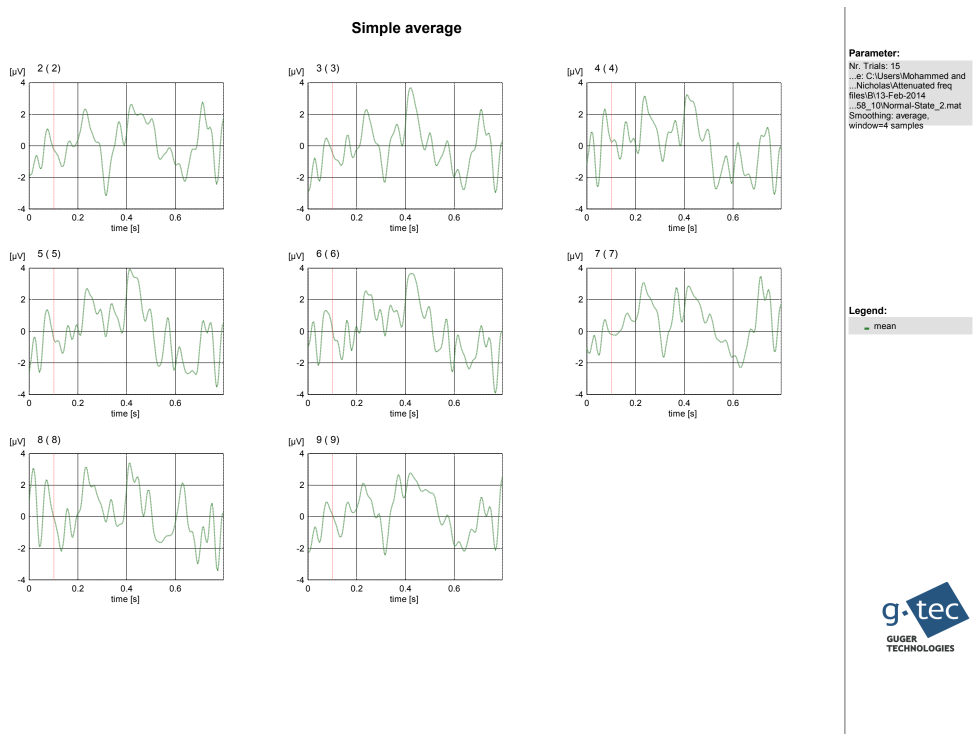

Figure 40 B2 x002 averaged

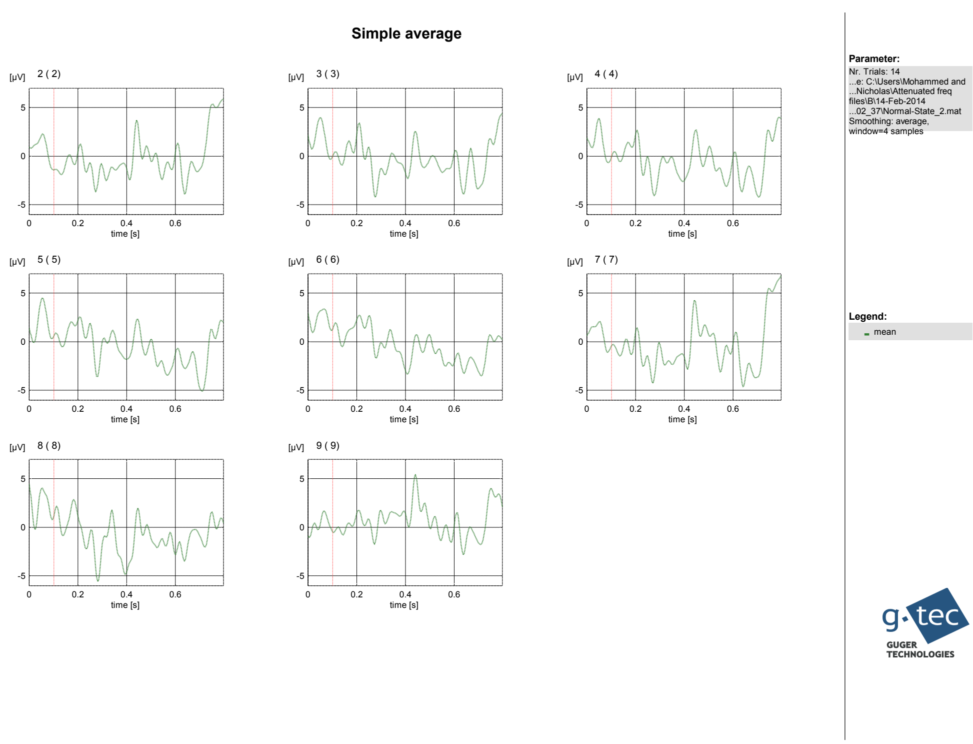

Figure 41 B3 x002 averaged

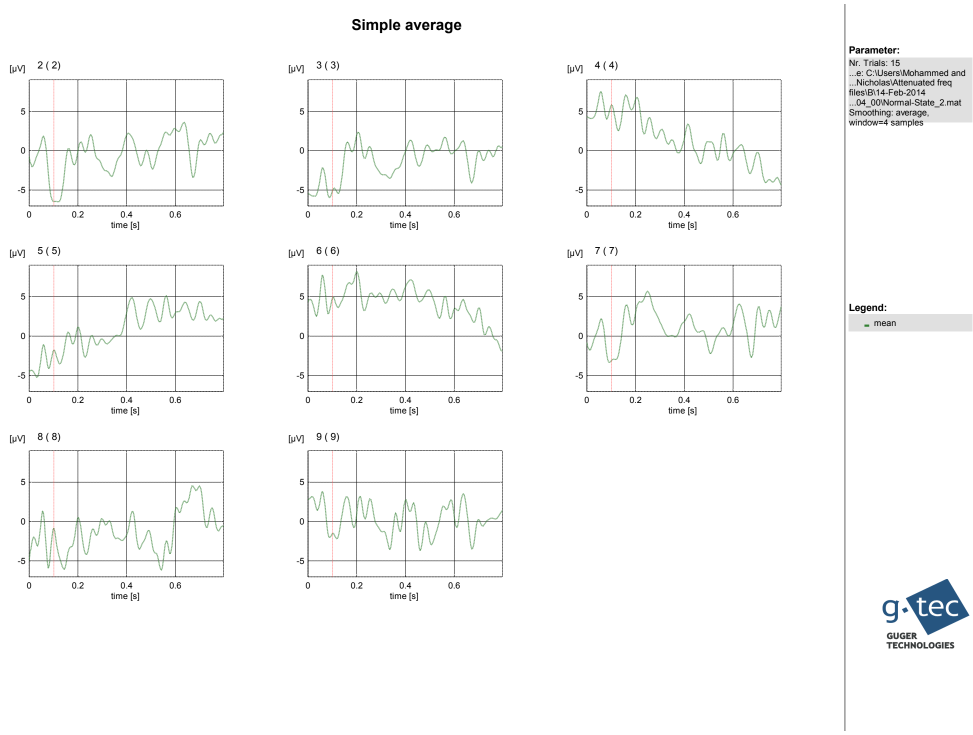

Figure 42 B4 x002 averaged

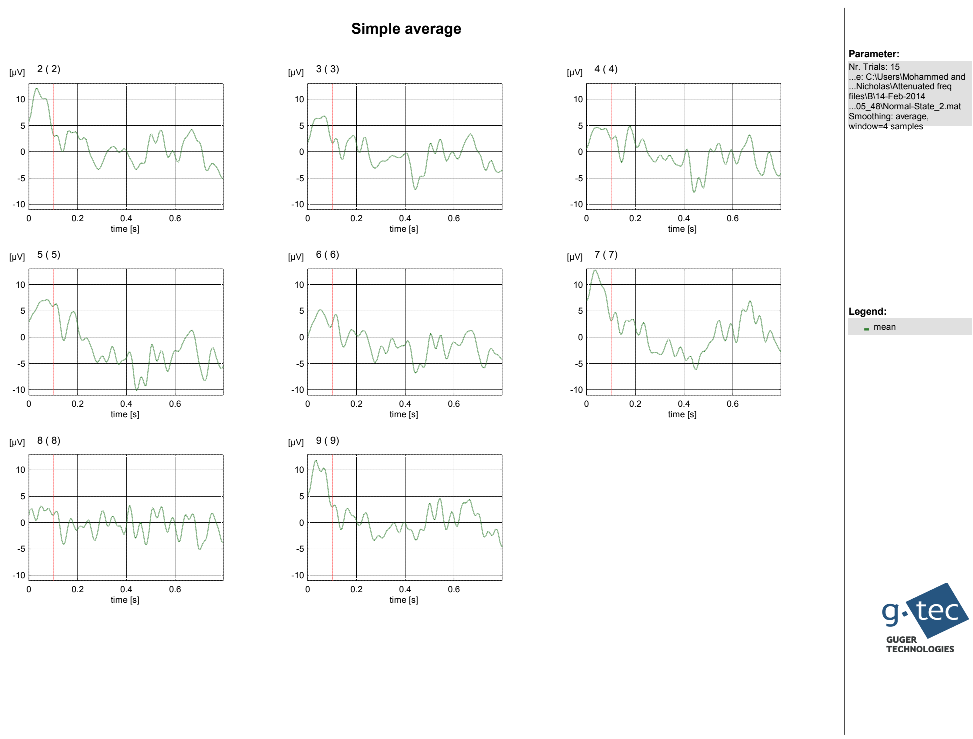

Figure 43 B5 x002 averaged

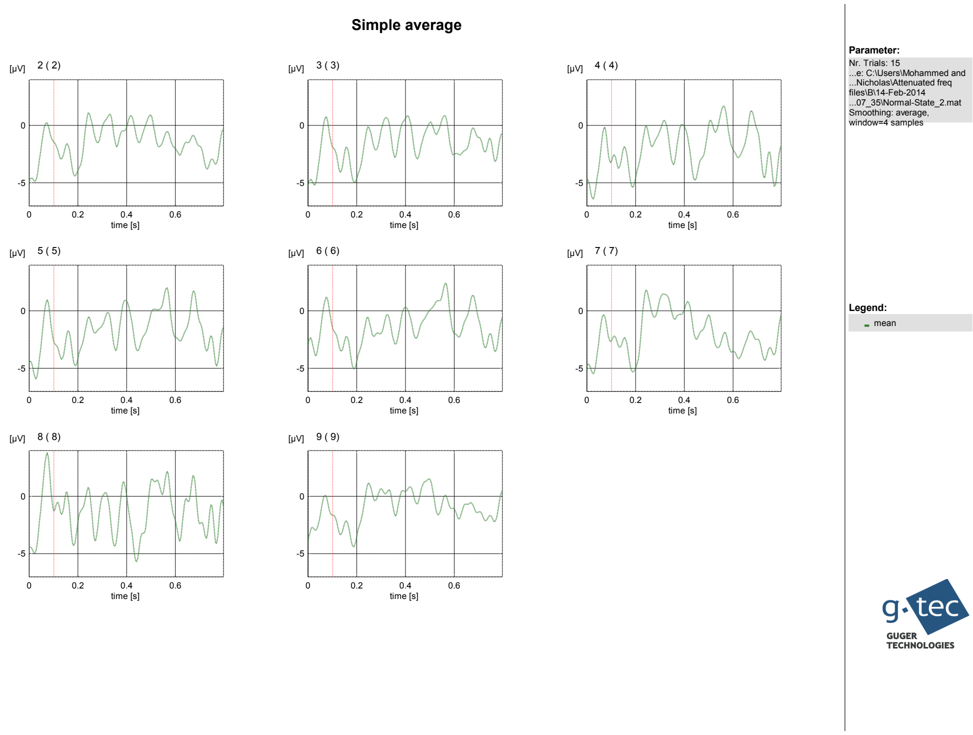

Figure 44 B6 x002 averaged

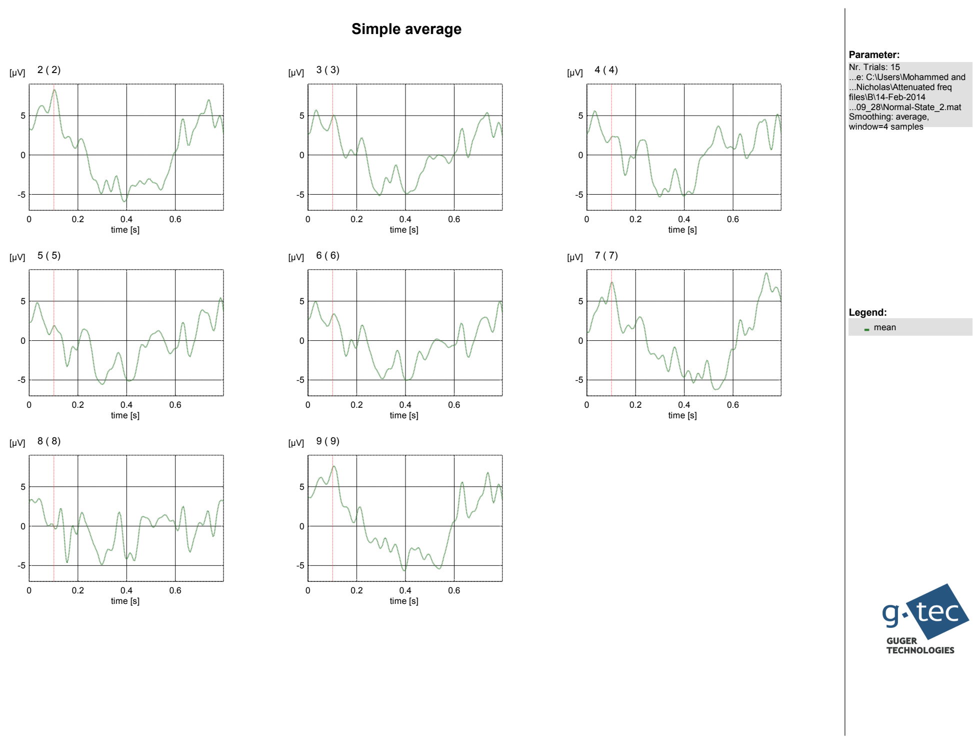

Figure 45 B7 x002 averaged

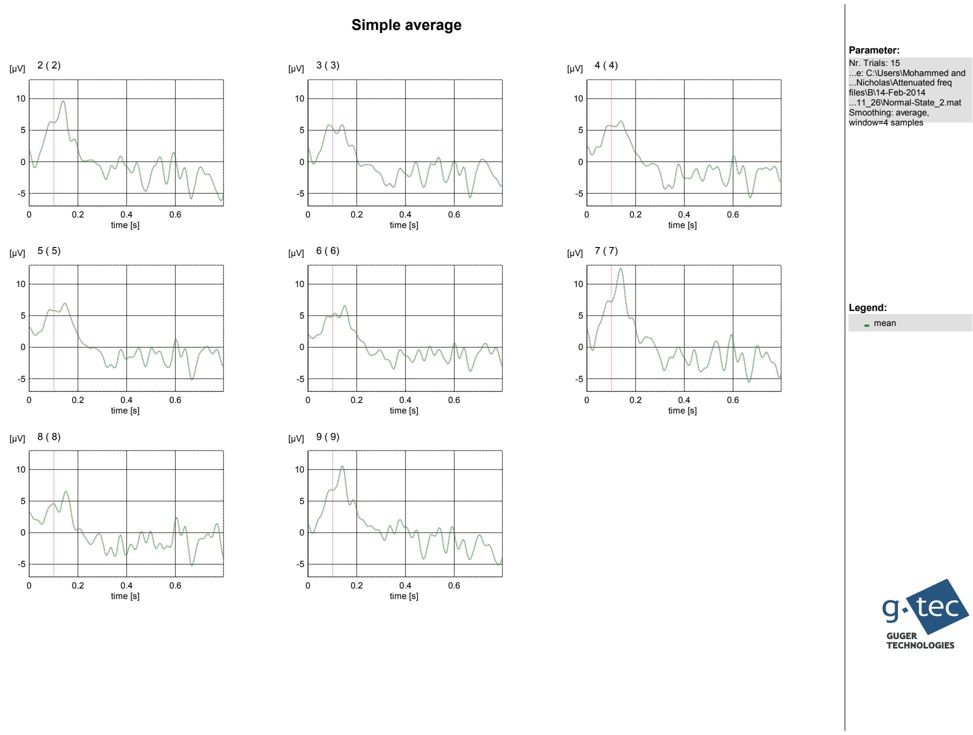

Figure 46 B8 x002 averaged

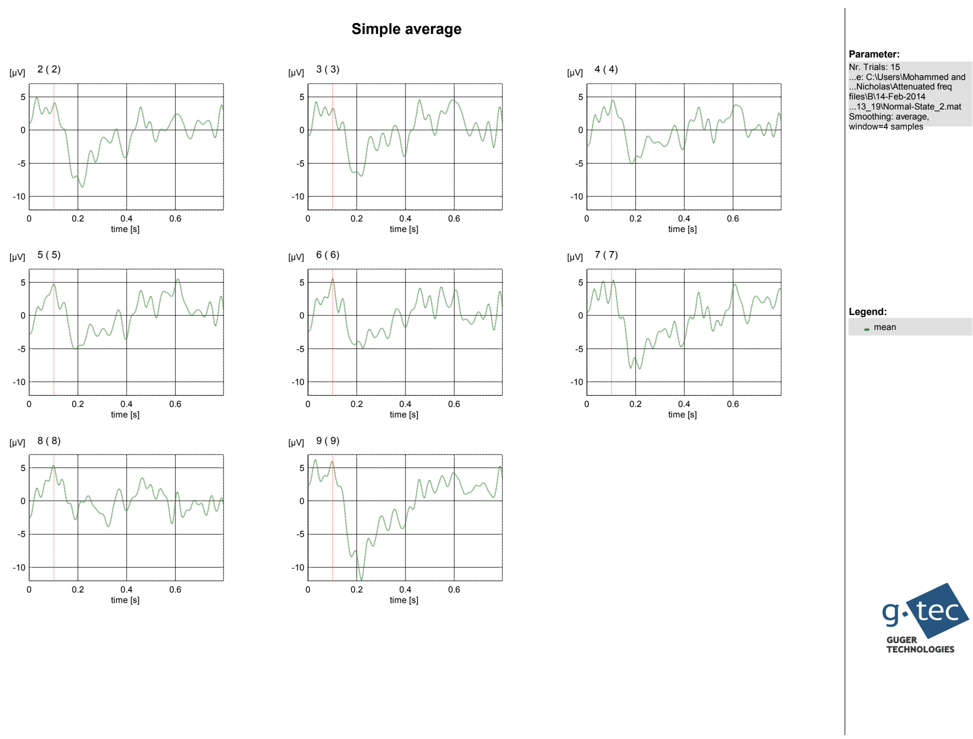

Figure 47 B9 x002 averaged

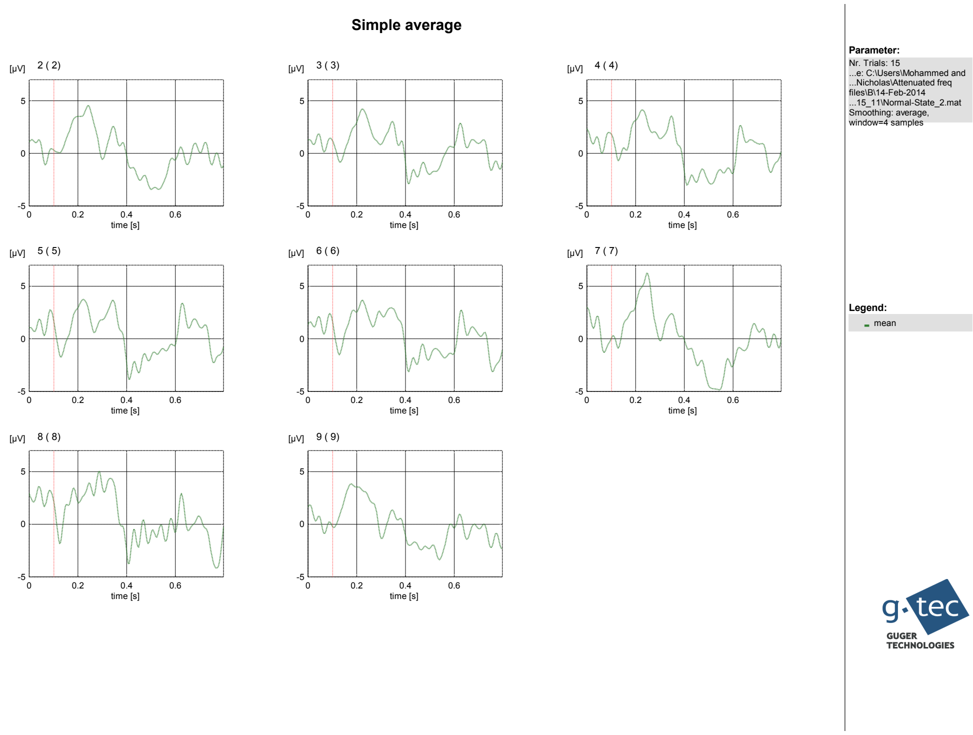

Figure 48 B10 x002 averaged

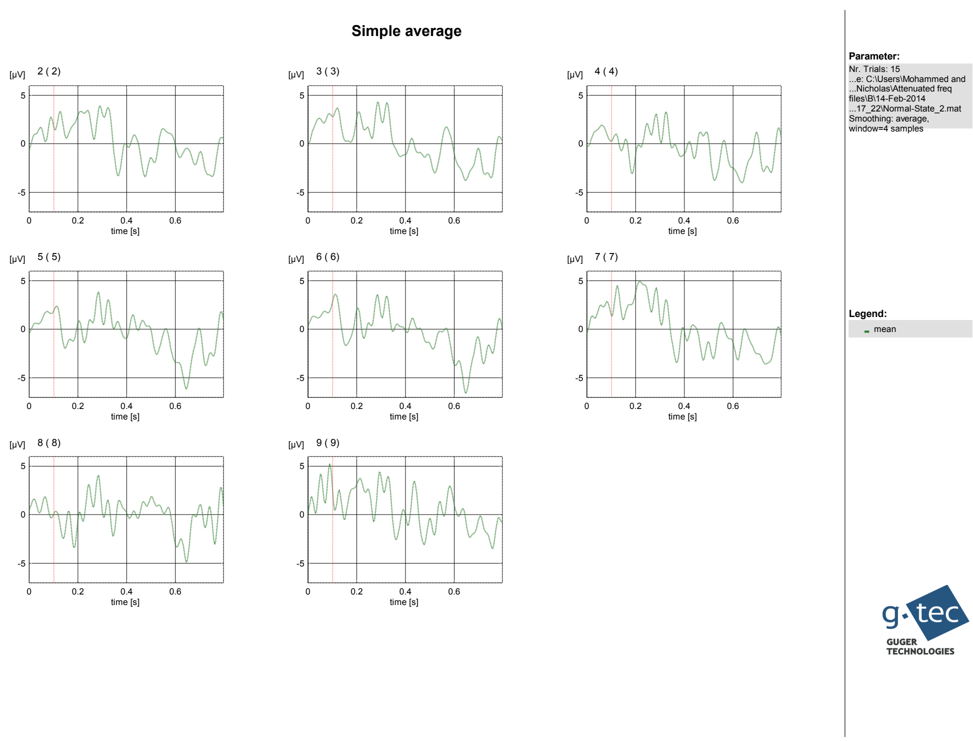

Figure 49 B11 x002 averaged

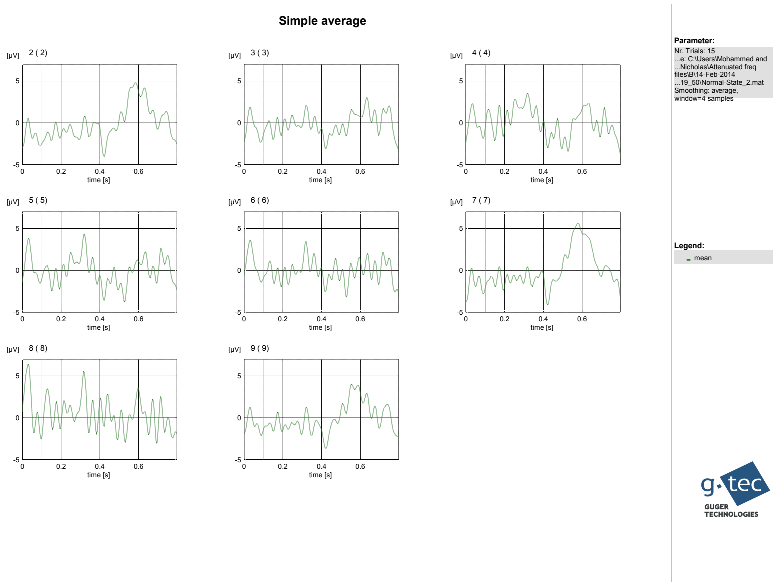

Figure 50 B12 x002 averaged

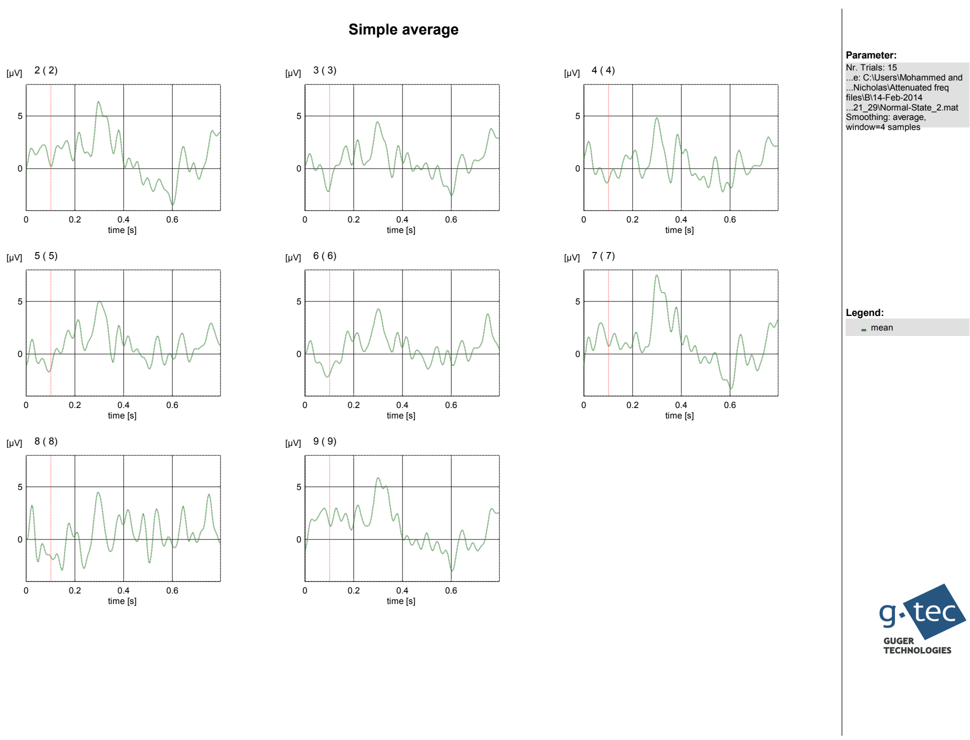

Figure 51 B13 x002 averaged

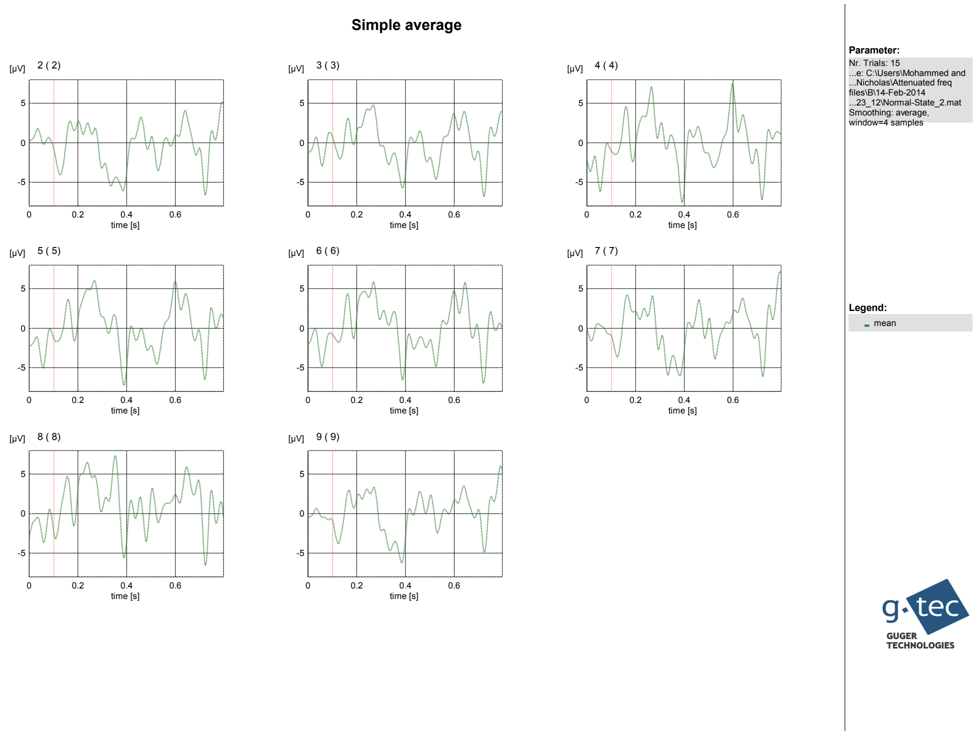

Figure 52 B14 x002 averaged

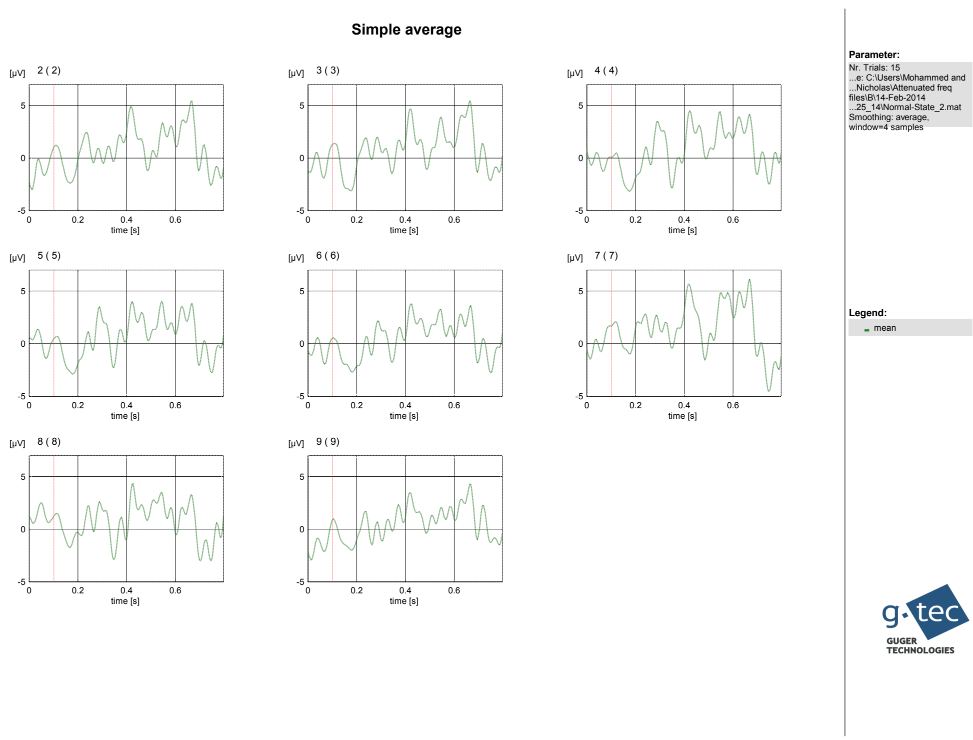

Figure 53 B15 x002 averaged

9.3 UDP Trigger scripts.

9.3.1 Trigger manager script.

```
using UnityEngine;
using System.Collections;
using System;
using System.Text;
using System.Net;
using System.Net.Sockets;
using System.Threading;
using System.Collections.Generic;
public class NickThesisTriggerManager : MonoBehaviour {
    private static List<String> triggerNames;
    private static int activeConfiguration = 0;
    private static int lastActiveConfiguration = 0;
    public float WrongControlsTimeout = 3f;
    private static float wrongControlsTimer = 0f;
    private static NickThesisTriggerManager instance;
    private enum States {Waiting, Trigger, ButtonPressed, TriggerTimeout};
    private static States state = States.Waiting;
    private static bool waitForPressAfterTimeout = false;
    void Start () {
        instance = this;
        init();
    }

    void Update () {
        switch (state)
        {
        case States.Trigger:
            if (Input.anyKey)
            {
                state = States.ButtonPressed;
                wrongControlsTimer = WrongControlsTimeout;
                //SendUDPMessage("Key Pressed After Trigger Enter");
                SendUDPMessage((lastActiveConfiguration * 1000) + 2);
            }
            break;
        case States.ButtonPressed:    //must not trigger if no button is being pressed!!!!!!
            if (wrongControlsTimer > 0f)
            {
                wrongControlsTimer -= Time.deltaTime;
                // reset to standard key layout
                if (wrongControlsTimer <= 0f)
                {
                    activeConfiguration = 0;
                    state = States.TriggerTimeout;
                    //SendUDPMessage("Trigger Timed Out - Keys set to normal");

                    SendUDPMessage((lastActiveConfiguration * 1000) + 3);

                    state = States.Waiting;
                    waitForPressAfterTimeout = true;
                }
            }
            break;
        case States.TriggerTimeout:
            if (Input.anyKey)
            {
                state = States.Waiting;
                //SendUDPMessage("Key Pressed After Trigger Timeout");
                SendUDPMessage((lastActiveConfiguration * 1000) + 4);
            }
            break;
```

```
    }

    if (waitForPressAfterTimeout) {
        if (Input.anyKeyDown)
        {
        SendUDPMessage((lastActiveConfiguration * 1000) + 4);
            waitForPressAfterTimeout = false;}}

}



private static bool AlreadyHad(String name) {
    if (triggerNames == null) triggerNames = new List<string>();

    if (triggerNames.Contains(name)) return true;
    else {
        triggerNames.Add(name);
        return false;
    }
}


public static void SetConfiguration(int value, String sender) {
    Debug.Log (sender + " wants to set config to " + value);
    if (!AlreadyHad(sender))
    {

    activeConfiguration = value;
    lastActiveConfiguration = value;
    state = States.Trigger;
    //SendUDPMessage("Trigger Entered - Keys set to " + activeConfiguration);
    //send udp message for only 1 sec. implement count down...
    SendUDPMessage((lastActiveConfiguration * 1000) + 1);
    waitForPressAfterTimeout = false;

    }

}

public static int Configuration {
    get { return activeConfiguration; }

}

// UDP stuff
private static int localPort;

// prefs
private string IP;  // define in init
public int port;  // define in init
// "connection" things
IPEndPoint remoteEndPoint;
UdpClient client;
// gui

string strMessage="";
public void init()

{

    print("UDPSend.init()");

    // define

    IP="10.8.0.1";

    port=8000;
```

```
//send

        remoteEndPoint = new IPEndPoint(IPAddress.Parse(IP), port);

        client = new UdpClient();

        // status

        print("Sending to "+IP+" : "+port);

        print("Testing: nc -lu "+IP+" : "+port);

    }

    // sendData

    private static void SendUDPMessage(int message)

    {
        Debug.Log ("MESSAGE"+" "+ message);
        try

        {


            byte[] data = BitConverter.GetBytes(message);
            instance.client.Send(data, data.Length, instance.remoteEndPoint);

        }

        catch (Exception err)

        {

            print(err.ToString());

        }

    }}
```

9.3.2 Trigger script

```
using UnityEngine;
using System.Collections;

public class NickThesisTrigger : MonoBehaviour {
   public int ConfigurationNumberToActivate = 0;

   // Use this for initialization
   void Start () {

   }
   // Update is called once per frame
   void Update () {

   }

   void OnTriggerEnter(Collider other) {
      if (other.gameObject.layer == LayerMask.NameToLayer("Player"))
      {
         //NickThesisTriggerManager.Configuration = ConfigurationNumberToActivate;
         NickThesisTriggerManager.SetConfiguration(ConfigurationNumberToActivate, gameObject.name);

         Destroy(gameObject);
            //transform.collider.isTrigger = false;
      }

   }
```

}

9.4 Input mapping of control changes during group A test

	Horizontal		Vertical		Explode	Jump	Mouse X	Mouse Y
	left	right	up	down				
Version								
0	a	d	w	s	mouse 0	space	Mouse X Axis normal	Mouse Y Axis normal
1	w	s	d	a	mouse 0	space	Mouse X Axis normal	Mouse Y Axis normal
2	s	w	a	d	space	mouse 0	Mouse Y	Mouse X
3	s	w	a	d	mouse 0	space	Mouse X Axis normal	Mouse Y Axis normal
4	d	s	w	a	mouse 0	space	Mouse X Axis normal	Mouse Y Axis normal
5	d	a	s	w	mouse 0	space	mouse y	Mouse X
6	w	a	s	d	space	mouse 0	mouse y	Mouse X
7	a	d	s	w	space	mouse 0	Mouse X Axis normal	mouse Y Axis normal
8	space	a	mouse 0	d	w	s	Mouse X Axis normal	Mouse Y Axis normal
9	a	d	w	s	mouse 0	space	Mouse Y	Mouse X
10	w	s	mouse 0	space	a	d	Mouse X Axis normal	mouse Y Axis normal
11	w	s	mouse 0	space	a	d	mouse Y	Mouse X
12	d	s	space	mouse 0	a	w	Mouse X Axis normal	mouse Y Axis normal
13	mouse 0	space	d	w	s	a	Mouse X Axis normal	Mouse Y Axis normal
14	space	mouse 0	d	s	w	a	Mouse Y	Mouse X
15	space	mouse 0	w	d	s	a	Mouse X Axis normal	Mouse Y Axis normal

9.5 Questionnaire:

Test nr.#*
Sex*

- m
- f

Age
Are you right or left handed?*Required

- R
- L

Rate your experience with 3rd person video games.*Required

	1	2	3	
little experience				a lot of experience

Have you played 3rd person games before?

- Yes.
- No.

Are you taking medication that influences the central nervous system?*Required

- Yes
- No

Have you experienced WASD mapping with mouse before?

- Yes.
- No.

PLEASE WAIT WITH THE REST OF THE QUESTIONNAIRE UNTIL AFTER YOU HAVE TAKEN THE TEST.*Required

- OK

Page 2 of 2

EEG Experiment. Post game.
Describe, in your own words, the story of the game.*Required
Describe, in your own words, the challenges during the game.*Required
Describe, in your own words, the abilities your character had in the game.*Required
Were there any areas in the game that you found challenging?*Required

Please answer to what extent do you agree with the following sentences.
The game experience felt awkward.*Required

	1	2	3	4	5	

not at all						very much

The game experinece felt smooth*Required

	1	2	3	4	5	
not at all						very much

9.6 Questionnaire answers

Test nr.#	Sex	Age	Are you right or left handed?	Rate your experience with 3rd person video games.	Have you played 3rd person games before?	Are you taking medication that influences the central nervous system?	Have you experienced WASD mapping with mouse before?
A1	f	29	R	2	Yes.	No	Yes.
B1	m	32	R	3	Yes.	Yes	Yes.
B2	m	31	R	3	Yes.	No	Yes.
A2	m	24	R	2	Yes.	No	Yes.
B3	f	27	R	3	Yes.	No	Yes.
A3	m	23	R	3	Yes.	No	Yes.
B4	m	27	R	3	Yes.	No	Yes.
A4	m	27	R	3	Yes.	No	Yes.
B5	f	28	R	1	Yes.	No	No.
A5	m	42	R	1	Yes.	No	Yes.
B6	m	25	R	3	Yes.	No	Yes.
A6	m	25	R	3	Yes.	No	Yes.
B7	m	28	R	2	Yes.	No	Yes.
A7	m	27	R	2	Yes.	Yes	Yes.
A8	m	30	R	3	Yes.	No	Yes.
B8	m	27	R	3	Yes.	No	Yes.
a9	m	26	R	1	Yes.	No	No.
B9	m	26	R	2	Yes.	No	Yes.
a10	m	26	R	3	Yes.	No	Yes.
B10	m	27	R	3	Yes.	No	Yes.
A11	m	26	R	2	Yes.	No	Yes.
B11	m	28	R	2	Yes.	No	Yes.
A12	m	23	R	3	Yes.	No	Yes.
b12	m	24	R	2	Yes.	No	Yes.
a13	m	27	R	3	Yes.	Yes	Yes.
B13	m	29	R	1	No.	No	Yes.
A14	m	28	R	2	Yes.	No	Yes.
B14	f	25	R	1	Yes.	No	No.
A15	f	26	L	1	No.	No	No.
B15	m	22	R	2	Yes.	No	Yes.

Participant Nr.	Describe, in your own words, the story of the game.
A1	siblings collected cans for living in a junk yard, and one day they meet a witch who took away the little sister and put a curse on the brother, big brother has to find his way through the junk yard to safe his sister.
B1	two siblings on a scrapyard on the search for a better life
B2	The is about a boy which losses his sister taken by a witch. The witch makes the boy magnetic. The boy now sets out on a quest to save his sister.
A2	You play a pure boy who collect cans to get money to pay for food. a witch(baglady) kidnaps and threathens to eat your sister and cast a magnetism spell on you. you use this ability and your ability to de-magnitise to hunt the witch
B3	It was the story about two orphans, who collected cans to get food. They ventured into a scrapyard to get cans, but encountered a witch who accused them of stealing. As a lesson, the witch took the sister and made the boy work like a magnet. The boy then tries to save his sister from the witch.
A3	2 poor childs collect cans in a scrapyard in means of surviving. When they are trying to get a huge amount of cans a witch comes and kidnaps the sister because shes furious that they stole cans. At the same time the brother gets magnetized so he will attract any metal object
B4	Find my way through the sprapyard and rescue my sister
A4	A boy and a girl (siblings) have to search for cans on a dangerous scrapyard, because they (probably) sell them and buy food. They are hungry. They find single cans at first, then they find a cart full of cans. They start picking up the cans in the cart when a witch appears. She is angry at them. She captures the girl and says that she is gonna feed her and finally eat her. She puts a spell on the boy that makes him magnetic. He can temporarly unmagnetise if the player concentrates. He starts chasing after the witch and stumbles upon a lot of challenges.
B5	brother and sister in a scrapyard. the sister gets kidnapped by a whitch. the which casts a spell on the buy, turning him magnetized. the boy goes to search for his sister in the scrap yard. beeing magnetized he attracts al things of metal in the scrap yard, making his journey difficult.
A5	Two children were hungry and looked for food in a scrapyard. A witch grabs the girl and curses the boy, so he becomes magnetic. He has to find the girl.
B6	Save the sister from the evil witch. Use awesome magnetic powers to overcome challenges
A6	Two orphans survive by recycling cans. They come to a scrapyard with many cans, but they are "attacked" by a witch that steals the little girl and curses the boy with extreme magnetism! The boy must save the girl, and his curse seems be rather useful at times!
B7	An impoverished brother and sister search for cans but unwittingly steal cans from a witch. The witch kidnaps the sister and curses the brother with magnetism. The brother is on a quest to save his sister.
A7	A boy and his sister is out collecting cans to survive. They find a shopping cart full of cans, but as they try to collect it, a witch appears and she is mad about the kids trying to take her cans. She kidnaps the girl, arguing that she is just stealing for food, like the kids. She curses the boy so that he is magnetic, attracting any can he finds. The boy sets out to rescue his sister, using to his advantage the curse that the witch has put on him.
A8	Me and my sister were hanging out in a scrapyard, and picked up a bunch of cans. An evil witch got mad about this, kidnapped my sister, and cursed me with the "ability" to attract cans and other metal objects. I then had to traverse the dangerous

	scrapyard to save my sister from the evil witch, using my new powers.
B8	A reinterpitation of the old HC andersen story, Hansel and Gretel. New story approach . find the sister, taken capture by the evil withc.
A9	The boy had to save his sister from an evil witch, but the evil with had put a spell on him, so he turned magnetic, which is an annoying thing, if you're running around the scrapeyard.
B9	Using your magnetic powers to attract or repulse the metallic material around to your advantage. Using the material as a weapon but also to manoeuvre around obstacles.
A10	Like in the fairy tale Hans and Grethe, I have to save the sister to the main caracter. She was taken away by a witch.
B10	A little boy's sister gets kidnapped by a witch and he is then determined to save her. Before the witch run off with the sister, she curses the little boy with "magnetic powers" where all metal objects are attracted to him, as if he was a magnet.
A11	BOY AND HER SISTER, COLLECTING CANS. WITCH KIDNAPPING SISTER, BOY HAS TO SAVE HER. HE IS CURSED WITH A MAGNETIC POWER. HE HAS TO USE HIS NEW POWER TO CLEAR THE SCRAPYARD
B11	2 children ciollecting cans to get money for food ends up in a scrap yard, where the collect the cans from a witch. she curses the boy and takes the girl with her. The cures the boy gets ends up bieng a power. the boy goes on in the search for his sister, throu the scrap yard using the his power/curse of magnitisem to get past diffrent obsticals. following a trail of cans his sister have layed out.
A12	Brother and sister collects cans for money, old bag lady gets mad and kidnaps the sister and puts a spell on the boy so he becomes magnetic. The boy has to save his sister
B12	Two sad young children are collect scrap for survival when an old witch takes his sister hostage. The witch also gives ham magnetic powers to slow down his progress. The boy then needs to rescue his sister from the witch by progressing through the puzzle game mastering his handicap in form of magnetism
A13	A boy collecting trash, needs to rescue his sister from the evil witch, who will feed her up and eat her. She has also given the boy a magnetic power, which he now uses to defeat obstacles on his way to rescue his sister.
B13	Two kids needed cans to get money to survive. When they try taking some cans that apparently belonged to an evil witch the girl gets kidnapped and the boy gets a magnetic curse.
A14	An interpretation of hansel and gretschel where two kids are wandering through a scrap yard. My job was to find the girl who was taken by the witch by solving puzzles, while dealing with my magnetic curse.
B14	Two siblings are searching for cans as an old lady catches the sister. The task is now to find her, to set her free. The brother has meanwhile got a spell upon him, making him magnetic too all kinds of metal.
A15	I am a boy which have to rescue my sister from a witch
B15	A boy and his sister is searching for cans in a scrapyard when they meet a witch who kidnaps the sister because she excuses stealing with hunger and she curse the boy to be magnetic. Then the boy has to find his sister passing dangers on his way.

Participant Nr.	Describe, in your own words, the challenges during the game.
A1	fighting against or go around those watch dogs or good timing in using the magnet power
B1	avoiding / managing the dogs - not dying
B2	Dogs, electrical fences, blockage, dangerous metal items
A2	use the de-magnitising ability correct and time the length (with your mind) to solve

	the puzzles.
B3	The game consisted of puzzles, where one needed to find out how to get through the scrapyard by using them magnetic power one had. You had to be careful to not attract sharp objects and to use the objects you attracted as weapons against the guard dogs. I would also call this a puzzle-challenge, as it seemed to be a matter of timing the moves correctly.
A3	Would say the challenge of the game was mostly puzzle based with some platforming as well. Attracting and throwing away metal as ways of completing different puzzle elements like getting a dog to stay away.
B4	The jumping was hard as the mouse was not very responsive or maybe too responsive
A4	Avoiding red items by unmagnetising when close to them. Avoiding dogs by finding a path around or killing them by unmagnetizing and sending sharp objects flying towards the dogs. Finding ways over things, using magnet cranes. Removing big items using magnetizm, to pass through areas. Pressing buttons, which i not always knew exactly what they did. I only noticed the one that is lifting a container. The framerate of the game was not the best. The mouse was not the best either, no mousepad. Sometimes the controls where scrambled for a few seconds: So that "w" was suddenly "walking sideways", and the same with the other keys.
B5	attracting heavy things in the scrap yard, making it difficult to walk. attracting sharp items, killing you. all the dogs biting you.
A5	Avoid predators (dogs) and lethal objects. Not get too burdened by metal, yet collect it at times when it's useful.
B6	Puzzles (how to come from A-B), avoid/kill enemies progress. Keep concentrated to sustain magnetic deenegizer.
A6	Figuring out puzzles. Not getting killed by attracting sharp objects. Escaping dogs. Dealing with weird control happenings (controls suddenly getting weird for a second)
B7	The dogs! Also, sometimes it was hard to know where to go but I don't think it would be confusing for most people.
A7	The control scheme seems out of place and multiple times during gameplay the buttons seemed to be switched around. This made it very challenging sometimes to solve the otherwise relatively simple puzzles. Especially areas with electric fences suffered from this.
A8	The controls seemed to be messing up my movement at times, taking control and moving me in the opposite directions. Mouse sensitivity was very high, the controls were a bit "floaty" causing a few deaths, and sometimes the camera was placed in unfortunate positions making it difficult to see where I was going. Also the dogs, electric fences and sharp objects were quite dangerous, but it seemed like me losing control of my character were what got me killed most often.
B8	Figure out how to move around the challenges, and even how to move them.
A9	finding right paths and solutions to get further.
B9	understanding what needs to be done to get through a blocked passage. Working out the best route.
A10	Since my character is magnetic, I faced challanges like being pulled into electric fences and taken damage by attracting sharp objects. The puzzles to solve was about getting past guard dogs and solving puzzles about how to get further in the level.
B10	The player is running around as a magnet, attracting most metal objects in his vesinity, the more object the player is carrying, the slower he moves. Giant magnets will pick him up and carry him around. During the game, the player encounters

	guard dogs which will attack and kill the player, should he get their attention. Some fences are electrified.
A11	THINKING ABOUT YOUR WEIGHT WITH/WITHOUT BEING MAGNATIZED. NOT TOUCHING THE ELECRICAL FENCES.
B11	Sharp object that possible hurt him, when the y get s attracted to him. Dogs on a leash that he can kill with un magnificing him self.. finding dirrection. movind refreguators by bouiling up a serten amount of mass.
A12	A puzzle game where the boy has to solve puzzles using his magnetic powers
B12	The puzzles, especially how to use the disadvantage of the magnetism as an advantage
A13	The dogs and electrical fences were a bit tough/unstable
B13	kid attracts a few a the metal objects on the scenes. some of them make him heavy, some of them damage him. and for some reason as he gets heavier, he also gets stronger.
A14	They were intruiging for the most part, some were a little difficult to solve either because I didn't know what to do or due to difficulty controlling my character
B14	My character's challenge was to control his magnetism and to take advantage of it! And to follow a lead of yellow cans.
A15	Get cans and stuff to move refridgerators, kill dogs and let huge magnet to transfer me around
B15	The dogs and the electric fence are the dangerous things whereas the real challenge is to find the easiest road through the scrapyard.

Participant Nr.	**Describe, in your own words, the abilities your character had in the game.**
A1	magnet power - attract cans and metals
B1	walk, jump, some sort of anti-magnetism
B2	Ability to attract/detract metal. Ability to jump and walk
A2	de-magnitise was an ability. however the fact that you were magnetic were also an ability you cound use to your advantage
B3	The character attracted magnetic materials, and the more materials were connected to him, the more the power amplified. By concentrating, he could cancel out the effect for a short time.
A3	As mentioned earlier i could run around, jump, attract metal and throw metal away.
B4	Magnetism, and the ability to supress the magnetism
A4	Jumping, rarely used. Picking up cans, only used in the beginning. Attracting metal objects of different sizes, depending on how much mass you already have attracted: Required to get through the levels. Pushing away the attracted metals sending them off flying and potentially killing angry dogs.
B5	he was able to reject the metal things and kill dogs with these. run fast. jump.
A5	He could demagnetize himself for a period of time, even repelling metal.
B6	Use magnetic powers to attract magnetic object to progress through the map and kill enemies and sovle puzzles
A6	Super Magnetism! The ability to attract metallic objects and repel them at will!
B7	To attract and repel metallic items
A7	Being a human magnet, with the ability to de-magnetize at will for a short period of time. Also whatever materials are stuck to the boy added to the strength of the magnetization.
A8	I could attract metal objects, and temporarily cancel out this ability. When carrying a lot of objects, cancelling the ability would expect said objects and could be used to kill the dogs. Also, when carrying heavy amounts of metal, I could carry increasingly

	heavily objects, like fridges. Also I could push down some weights if I was carrying enough metal.
B8	Ability to be, and not be magnetic.
A9	My character could move around, kill dogs (!), move stuff, especially by gaining weight, and hopefully save his sister.
B9	The character was made magnetic, he nonetheless has the ability to momentarily stop this effect if he concentrates really hard.
A10	he was magnetic, attracting all metal objects, becoming heavier and heavier. The other ability is to release all the metal in kind of metal-nova :D
B10	The player has the ability to "de-magnitise" himself, and in doing so sends all object attached to him flying away from him. He can jump.
A11	BEING MAGNATIZED AND BEING ABLE TO UN-MAGNATIZE. USING THE WEIGT OF MATERIALS BOUND TO YOUR BODY
B11	He attract metal, and can demagnitise thus forcing the metal out in a small parimiter witch he can use as an aoe attack and at the same time he does not attract new metal. the more metal he is carrieng the slower he move and can jump less, but he also have bigger magnectic power.
A12	The boy can "suck" metallic items towards him
B12	Atrract and detract metallic objects, which is useful for e.g. gaining extra weigth to interact with buttons, or trow metalic obstacles at the enemy / dogs.
A13	collect items, demagnetize, navigate and jump
B13	ability to attract metal objects and ability to for a few moments lose the previous ability.
A14	Being magnetic I could move things and be "transported" by the cranes. I could also change the amount of magnetism by collecting more garbage.
B14	He had the abilities to load himself with magnetism and to let it all go again.
A15	I am magnetic so I can collect things to my body which gives me the strength to control the game and the dangers that comes in way
B15	he could jump, and he could either attract metallic itms or blast them away using them as a weapon

Participant Nr.	Were there any areas in the game that you found challenging?
A1	ja, trying to go around the watch dogs without dying
B1	in the second level - the part with the crane and the electric fences where you had to walk underneath the crane without it pulling you up against a fence
B2	Yes, at some point I didn't know how to progress. Needed help from the observer
A2	Anyplace with the dogs was difficult. and long paths with lots of knives since you really had to concetrate to stay de-magnitised
B3	Yes, I needed to think a bit on how to remove bigger objects (by attracting smaller objects) and how best to get rid of the dogs.
A3	The puzzles had a nice challenge to them. The platforming would have been easy if it werent for the bugs in the controls. "Sometimes the mouse direction switched for a couple of seconds, or the character might begin running in a different direction than asked."
B4	Yes, the jumping was rather a challenge but not to bad
A4	The dogs without leashes were unpredictable. Also the attracted objects were flying in unexpected directions when i demagnetized, which made it hard to kill dogs. The puzzle parts of the game were not so challenging.
B5	finding the way. avoiding the dogs.
A5	Yes, at some points I forgot my orientation after respawn. Needed some time to

	consider some of the puzzels. But didn't sleep much last night, so...
B6	Passing the first dog (didnt know i could "simply" kill it). Navigating narrow electric fences.
A6	Dogs! Anywhere with dogs. Especially those without leash.
B7	Not particularly.
A7	As mentioned above, all areas with electric fences. Also solving the puzzle where you needed to move a fridge and a safe were a bit challenging as I wasn't aware in the beginning, that the pulling force was increased with the amount of items.
A8	I thought the part where I had to move the two fridges which were in the middle of two electric fences, and there was a magnet carrying me between the fences was quite difficult, because I couldn't quite figure out how to move them. Also, in the beginning there was a sequence where I had to push down a button to move a shipping container, and it seemed like I couldn't quite get it to do what I wanted. The end part, right where I was stopped, was quite difficult because it was difficult to move between the electric fences without getting zapped.
B8	Most of them, the game appears to be easy, yet, a lot of thinking is required to figure out that you are able to do things that might not seem possible initially.
A9	sometimes it was hard to find solutions for puzzles, I found a bit difficult to navigate or fint the right parh.
B9	At first I was unaware I could move objects when heavy enough.
A10	yes, but it was ballanced well. No frustration.
B10	The guard-dogs were hard to hit at times, when trying to kill them by "firing" objects at them. Mostly because i could not always determine which way the objects would fly.
A11	ALL. HAD A BIT OF A DIFFICULT TIME WITH THE ROUTE AND CONTROLS IN THE GAME. CAMERA ANNOYING SOMETIMES.. DIED A LOT OF TIMES THE SAME PLACES, BUT MOSTLY BECAUSE OF THE ELECTRIC FENCES (AND DOGS)
B11	a place where i needed both to have quite abit og metal with me, to move a refreguator and to demagnitice to get of a moving magnet.
A12	There was a pressure plate I didn't know how to use
B12	Due to a bug a little. But i was mostly stuck in one scenario where i had to open a container to continue, i didn't realize i could do the run so i thorught there was another way.. Sometimes the control was a bit challenging aswell, but as soon as you get to know the sensitivity of the movements i suppose it would be better
A13	yes, the area with the three dogs
B13	it is difficult to differentiate between one area and the next as there is insufficient contrast. kid getting stronger or more powerful when heavy makes no sense to me. camera movement is jerky, faster computer and smother graphics recommended. it is difficult to spot objects which could damage character (knifes, etc). Fences are somewhat invisible in some situations.
A14	Yes, the first time I had to move the fridge by adding more garbage. I didn't understand that.
B14	The largest challenge was for me to control the directions and view with the mouse and keyboard and to figure out, in which direction I came from! But after being told the solutions to my doubts it all went a little smoother!
A15	Yes, how to move between areas, and understanding of the game. The colours were similar and difficult to see dangers and what was what.
B15	the part when you have electric fence above you and dogs on the other side

Participant Nr.	The game experience felt awkward.	The game experience felt smooth
A1	4	2
B1	3	3
B2	3	4
A2	3	4
B3	1	3
A3	4	2
B4	2	2
A4	2	3
B5	1	5
A5	2	4
B6	3	4
A6	4	3
B7	1	4
A7	5	2
A8	4	2
B8	2	4
A9	2	3
B9	2	4
A10	1	3
B10	1	4
A11	3	3
B11	1	4
A12	3	4
B12	2	4
A13	4	2
B13	3	2
A14	1	3
B14	4	2
A15	4	2
B15	2	4

9.7 Matlab script

9.7.1 Divide EEG data into 8 files

```
% variables
lowerBoundOffset = 24.6;
upperBoundOffset = 230.4;

% getting the trigger row
trigger = y(10, :);

%what is the value of the first element?
first = trigger(1);

foldername = datestr(now());
foldername = strrep(foldername, ':', '_');
```

```
mkdir(foldername);

normalTriggers = {y(:, :), y(:, :), y(:, :), y(:, :)};
triggerSixteen = {y(:, :), y(:, :), y(:, :), y(:, :)};


i = 1;
filenumber = 1;
triggerState = 0;
firstDigits = 0;

while (i<=max(size(trigger)))
    % find the first value that is different

    if trigger(i) ~= first
        % value is different

        % get first and last digits
        first = trigger(i);
        %firstString = num2str(first);

        firstDigits = fix(first / 1000);
        lastDigit = first - firstDigits * 1000;

        % NORMAL TRIGGERS
        if firstDigits < 16
            if triggerState ~= 1 && lastDigit == 1 % any state to state 1
                normalTriggers{1,1}(10, i) = 1000; % 1
                normalTriggers{1,2}(10, i) = 0;
                normalTriggers{1,3}(10, i) = 0;
                normalTriggers{1,4}(10, i) = 0;
            elseif triggerState == 1 && lastDigit == 2 % 1 to 2
                normalTriggers{1,1}(10, i) = 0;
                normalTriggers{1,2}(10, i) = 1000; % 2
                normalTriggers{1,3}(10, i) = 0;
                normalTriggers{1,4}(10, i) = 0;
            elseif triggerState ~= 1 && lastDigit == 2 % state 0, 3 or 4 to state 2
                normalTriggers{1,1}(10, i) = 1000; % 1
                normalTriggers{1,2}(10, i) = 1000; % 2
                normalTriggers{1,3}(10, i) = 0;
                normalTriggers{1,4}(10, i) = 0;
            elseif triggerState == 2 && lastDigit == 3 % from 2 to 3
                normalTriggers{1,1}(10, i) = 0;
                normalTriggers{1,2}(10, i) = 0;
                normalTriggers{1,3}(10, i) = 1000; % 3
                normalTriggers{1,4}(10, i) = 0;
            elseif triggerState == 2 && lastDigit == 4 % from 2 to 4
                normalTriggers{1,1}(10, i) = 0;
                normalTriggers{1,2}(10, i) = 0;
                normalTriggers{1,3}(10, i) = 1000; % 3
                normalTriggers{1,4}(10, i) = 1000; % 4
            elseif lastDigit == 3 % from whatever to 3
                normalTriggers{1,1}(10, i) = 0;
                normalTriggers{1,2}(10, i) = 0;
                normalTriggers{1,3}(10, i) = 1000; % 3
                normalTriggers{1,4}(10, i) = 0;
            elseif lastDigit == 4 % from whatever to 4
                normalTriggers{1,1}(10, i) = 0;
                normalTriggers{1,2}(10, i) = 0;
                normalTriggers{1,3}(10, i) = 0;
                normalTriggers{1,4}(10, i) = 1000; % 4
            end


            triggerSixteen{1,1}(10, i) = 0;
            triggerSixteen{1,2}(10, i) = 0;
            triggerSixteen{1,3}(10, i) = 0;
            triggerSixteen{1,4}(10, i) = 0;
        else % TRIGGER TYPE 16
```

```
            if triggerState ~= 1 && lastDigit == 1 % any state to state 1
                triggerSixteen{1,1}(10, i) = 1000; % 1
                triggerSixteen{1,2}(10, i) = 0;
                triggerSixteen{1,3}(10, i) = 0;
                triggerSixteen{1,4}(10, i) = 0;
            elseif triggerState == 1 && lastDigit == 2 % 1 to 2
                triggerSixteen{1,1}(10, i) = 0;
                triggerSixteen{1,2}(10, i) = 1000; % 2
                triggerSixteen{1,3}(10, i) = 0;
                triggerSixteen{1,4}(10, i) = 0;
            elseif triggerState ~= 1 && lastDigit == 2 % state 0, 3 or 4 to state 2
                triggerSixteen{1,1}(10, i) = 1000; % 1
                triggerSixteen{1,2}(10, i) = 1000; % 2
                triggerSixteen{1,3}(10, i) = 0;
                triggerSixteen{1,4}(10, i) = 0;
            elseif triggerState == 2 && lastDigit == 3 % from 2 to 3
                triggerSixteen{1,1}(10, i) = 0;
                triggerSixteen{1,2}(10, i) = 0;
                triggerSixteen{1,3}(10, i) = 1000; % 3
                triggerSixteen{1,4}(10, i) = 0;
            elseif triggerState == 2 && lastDigit == 4 % from 2 to 4
                triggerSixteen{1,1}(10, i) = 0;
                triggerSixteen{1,2}(10, i) = 0;
                triggerSixteen{1,3}(10, i) = 1000; % 3
                triggerSixteen{1,4}(10, i) = 1000; % 4
            elseif lastDigit == 3 % from whatever to 3
                triggerSixteen{1,1}(10, i) = 0;
                triggerSixteen{1,2}(10, i) = 0;
                triggerSixteen{1,3}(10, i) = 1000; % 3
                triggerSixteen{1,4}(10, i) = 0;
            elseif lastDigit == 4 % from whatever to 4
                triggerSixteen{1,1}(10, i) = 0;
                triggerSixteen{1,2}(10, i) = 0;
                triggerSixteen{1,3}(10, i) = 0;
                triggerSixteen{1,4}(10, i) = 1000; % 4
            end

            normalTriggers{1,1}(10, i) = 0;
            normalTriggers{1,2}(10, i) = 0;
            normalTriggers{1,3}(10, i) = 0;
            normalTriggers{1,4}(10, i) = 0;
        end

        triggerState = lastDigit;
        %lowerBound = i - lowerBoundOffset;
        %upperBound = i + upperBoundOffset;



        %filenumber = filenumber + 1;
    else
        % zero out everything we dont need
        normalTriggers{1,1}(10, i) = 0;
        normalTriggers{1,2}(10, i) = 0;
        normalTriggers{1,3}(10, i) = 0;
        normalTriggers{1,4}(10, i) = 0;

        triggerSixteen{1,1}(10, i) = 0;
        triggerSixteen{1,2}(10, i) = 0;
        triggerSixteen{1,3}(10, i) = 0;
        triggerSixteen{1,4}(10, i) = 0;
    end
    %is the
    i = i + 1;
end

%save whatever into a file
snippet = normalTriggers{1, 1};
```

```
snippet = snippet.';
filename = [foldername '/' 'Normal-State_1'];
save(filename, 'snippet');

snippet = normalTriggers{1, 2};
snippet = snippet.';
filename = [foldername '/' 'Normal-State_2'];
save(filename, 'snippet');

snippet = normalTriggers{1, 3};
snippet = snippet.';
filename = [foldername '/' 'Normal-State_3'];
save(filename, 'snippet');

snippet = normalTriggers{1, 4};
snippet = snippet.';
filename = [foldername '/' 'Normal-State_4'];
save(filename, 'snippet');

snippet = triggerSixteen{1, 1};
snippet = snippet.';
filename = [foldername '/' 'Sixteen-State_1'];
save(filename, 'snippet');

snippet = triggerSixteen{1, 2};
snippet = snippet.';
filename = [foldername '/' 'Sixteen-State_2'];
save(filename, 'snippet');

snippet = triggerSixteen{1, 3};
snippet = snippet.';
filename = [foldername '/' 'Sixteen-State_3'];
save(filename, 'snippet');

snippet = triggerSixteen{1, 4};
snippet = snippet.';
filename = [foldername '/' 'Sixteen-State_4'];
save(filename, 'snippet');
```