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**Written all over our faces? – Facial expressions occurring during and after the  
process of lying**

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## **Abstract**

Distinguishing between truth and lie is a crucial task for a wide range of professions and departments, such as police officers, insurance companies, security personnel and judges. (cf. Vrij and Fisher, 2020, p. 1) But how do signs of lying and deceit manifest themselves in human non-verbal behavior? Which cues can be observed on the liars faces when they are lying? And are indications of deception really limited to the period of the actual lie? Or do liars also show signs of deception when they feel like they have gotten away with their lie?

These are the questions the master thesis at hand aims to answer. By conducting a cluster analysis of the collected data, the study at hand aims to analyze and identify possible patterns in facial expressions and their combinations during and immediately after lying. To do so, new data is collected through a quantitative exploratory experiment, in which participants' reactions to visual stimuli as well as their expressions when and after lying are recorded. The cluster analysis shows that liars tend to blink more often and show less signs of emotional engagement on their faces, than truth tellers. When it comes to the moment after a lie is believed, liars can be divided into two groups: (1) showing duping delight, and (2) suppressing signs of duping delight and keeping a mostly neutral face.

**Key words:** Cluster Analysis, Lie Detection, Non-Verbal Human Behavior, Emotion Analysis, Eye Tracking

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## List of abbreviations

|         |                                                     |
|---------|-----------------------------------------------------|
| ANN     | Artificial Neural Network                           |
| AU      | Action Unit                                         |
| AUs     | Action Units                                        |
| B2B     | Business-to-Business                                |
| CNS     | Central nervous system                              |
| EmoPicS | Emotional Picture Set                               |
| FACS    | Facial Action Coding System                         |
| GBV     | Gesamtverband der Deutschen Versicherungswirtschaft |
| IAPS    | International Affective Picture System              |
| SD      | Standard Deviation                                  |
| SSE     | Sum of Squared Errors                               |

# 1. Introduction

Basically, every human has lied at least once in their life. Diary studies of Bella DePaulo et al. have shown, lies in fact are part of our daily life. The adult participants of the study told in average one lie a day. The college student participants even two. (cf. DePaulo et al., 1996, p. 991) Lying occurs for a variety of reasons: to avoid tension or conflict, preserve interpersonal relationships, obtain situational control in social interactions, to save face in front of others, or to simply exploit interpersonal power. (cf. Edgley, Olmstead and Turner, 1975, p. 77; cf. Bryant, 2008, p. 25)

Distinguishing between truth and lie is a crucial task for a wide range of professions and departments, such as police officers, insurance companies, security personnel and judges. (cf. Vrij and Fisher, 2020, p. 1) A study from the Gesamtverband der Deutschen Versicherungswirtschaft (GBV) shows that approximately 9 % of all insurance cases are considered dubious cases, indicating, that insurance fraud may have occurred. The study also shows that most dubious cases are reported in personal liability insurance. Whereas some people think that insurance fraud is forgivable to some degree, the insurance company is faced with an approximated yearly financial loss of 4-5 billion Euros. A loss caused by deceptive but carried out on the back of truthful insurance clients. (cf. Wenig, 2017)

Not only in the insurance but also in the online marketing and E-commerce sector lie detection or credibility checks gain increasing significance as well – on both the customer and the business side. As more and more business transactions and purchases nowadays are conducted virtually, the most effective form of communication in sales – at least in the Business-to-Business (B2B) sector – the face-to-face sales pitch, is gradually drifting into the online spectrum as well. (cf. Schlesiger, 2020; cf. Carnevale et al., 2021, p. 3)

For all sectors mimics, gesture, and behavior of the customer deliver valuable information for lie detection and credibility of their customers. Lie detection can be achieved through measuring (1) brain activity, (2) physiological responses, (3) speech content or (4) non-verbal behaviors. Amongst these methods, non-verbal lie detection is particularly favorable, as it neither requires any additional equipment nor the target person to speak. (cf. Vrij and Fisher, 2020, p. 1; cf. Carnevale et al., 2021, p. 17) According to Charlotte Anabelle De Brabandt – procurement and supply chain expert – the use of speech and facial expression evaluation

software to analyze the customers emotions and behavior will increase, as digitalization progresses further. (cf. Beschaffung aktuell, 2020; cf. De Brabandt, 2020, p. 8) Human behavior research software is not new to the market. The iMotions A/S for example is an IT company specializing in this field. The iMotions software is a hardware-independent platform that integrates and synchronizes multiple biosensors such as eye tracking and facial expression analysis in a single application and hence allows the evaluation of human behavior. (cf. iMotions, no date)

But how do signs of lying and deceit manifest themselves in human non-verbal behavior? Which cues can be observed on the liars faces when they are lying?

Multiple studies have investigated these questions before, by analyzing the individual effect of non-verbal indicators, such as blink rate, eye, head, and face movements, to find one diagnostic indicator for deceit, as shown by a meta-analysis of DePaulo et al. and a meta-analysis by Bond and DePaulo. (cf. DePaulo et al., 2003, p. 90ff.; cf. Bond and DePaulo, 2006, p. 219ff.) But the effect of combinations of non-verbal indicators as indication for deceit comes up short. (cf. Vrij and Fisher, 2020, p. 5) Furthermore, the existing studies limit their investigations to the period of the actual lie.

This raises the question if indications of deception are really limited to the period of the actual lie? Or do liars also show signs of deception when they feel like they have gotten away with their lie?

The present study makes a first attempt to analyze the combinations of nonverbal facial indicators during and, for the first time, after lying. To do so, an experiment including recorded narrative interviews is conducted, where participants are instructed to deliberately lie and convince an observer that they in fact are telling the truth. The recordings are made directly via the iMotions 10.0 software and undergo preprocessing (emotion analysis) within the software. The collected data include eye tracking recordings and recordings of the face. Based on the collected data, a cluster analysis using the sklearn.cluster.KMeans toolkit is conducted, to analyze the combinations of non-verbal facial indicators.

Before starting into the cluster analysis, the paper at hand first defines the terminology and introduces a definition of lying. As lies can take on different forms a typology of different kinds of lies is established afterwards. Once the terminology on lies and lying is set, the present

paper turns on non-verbal lie detection, introducing one of the most influential researchers in the field of non-verbal human behavior, Paul Ekman. His elaborations and definitions on non-verbal behavior in the context of lying, due to their impact on the scientific discourse, build the theoretical groundwork for the study at hand. As according to Ekman emotion and lying are linked, emotion theories are introduced to investigate the linkage of emotion and lying further. After discussing the main relation between the two subjects, the current state of research on the topic of non-verbal lie detection is presented.

Derived from the theoretical background, the next section unveils the experimental setup, as well as the data collection and evaluation methods used for conducting the narrative interviews and analysis of the collected data. The following chapter focusses on the analysis of the collected data and comprises the results of the cluster analysis, as well as possible exclusion criteria for certain data points. The next chapter then interprets the findings of the study and shows similarities and dissimilarities between already existing research findings and the findings within the study at hand. Lastly, the conclusion summarizes the main findings and puts them in context with the research question.

## 2. Theoretical Background

### 2.1 Definition of Lying

The definitions of lying are manifold, but the most widely accepted definition of lying is that **lying** is “To make a believed-false statement to another person with the intention that the other person believes that statement to be true” (Mahon, 2016). According to this definition, for lying four conditions need to be fulfilled:

- (1) The **statement condition** – lying requires a person to make a statement.
- (2) The **untruthfulness condition** – lying requires the given statement to be untruthful.
- (3) The **addressee condition** – lying requires the untruthful statement to be addressed to another person.
- (4) The **intention to deceive the addressee condition** – lying requires the addressee of the lie to believe the untruthful statement to be true.

Regarding non-verbal lie detection, especially the statement condition is of major interest. As claimed by the statement condition, making a statement requires the use of language, including conventional symbols, icons, or indices. (cf. Mahon, 2016) In the field of study of nonverbal behavior on the other hand, lying is defined as “any form of behavior [with the function] to provide others with false information or to deprive them of true information” (Smith, 2004, p. 14), clearly objecting the statement condition. According to this definition, lying can be verbal or nonverbal, conscious, or unconscious, and can consist of simply withholding information without making a statement at all. (cf. Ekman, 2001, p. 28; cf. Smith, 2004, p. 14)

### 2.2 Typology of Lies

As part of deception, lying is typically sorted into the category of **aversive interpersonal behavior**. This category includes any mean and unkind behavior people are exposed to on a regular and frequent basis. (cf. Kowalski et al., 2003, p. 472; cf. Bryant, 2008, p. 24)

But, in society not all lies are viewed as equally severe and mean. Some lies are even accepted because they may protect someone from being hurt by an unnecessary truth. The variation in perceptions of aversive interpersonal behavior, such as lying, becomes clearly apparent when the recipient's and sender's perception of aversiveness are discussed. Hence, aversive

behavior can be individually judged based on the lie's effects, directness, intention, and degree to which the existing relationship of the people involved is impacted or harmed. (cf. Kowalski et al., 2003, p. 472; cf. Bryant, 2008, p. 25) Grouping all lies into one category therefore is misleading. (cf. Bryant, 2008, p. 23) The following subsection takes a closer look on different types of lies and how they affect human communication and behavior.

Throughout varying fields of research, lies can be broadly clustered into two categories. Only in the differentiation between the categories as well as the labeling of the two categories, researchers differ. For example, some researchers break up lies into benign and exploitive lies. **Benign lies** are lies "engineered in the interest of the person contained by them, or, if not quite in his interest and for his benefit, then at least not done against his interest." (Goffman and Berger, 1986, p. 87). Hence benign lies are considered harmless and acceptable. **Exploitive lies** on the other hand "contain others in a construction that is clearly inimical to their private interests" (Goffman and Berger, 1986, p. 103). Therefore, exploitive lies are considered harmful and unacceptable. Whereas benign liars are not morally corrupted by their lies, exploitive liars are prone to social stigmatization. (cf. Hopper and Bell, 1984, p. 299; cf. Goffman and Berger, 1986, p. 87ff.; cf. Bryant, 2008, p. 25f.)

Another taxonomy initiated through the studies of DePaulo et al. in 1996, identifies even three types of lies: (1) outright lies, (2) exaggerations, and (3) subtle lies. **Outright lies** are lies that convey the information thoroughly contradictory to the truth. When a liar overemphasizes facts, he uses **exaggerations** that exceed the truth. Lastly, **subtle lies** occur when telling true information, but omitting relevant details pretending to tell the whole truth. This also includes nonverbal and behavioral lies. The study makes another distinguishment between self-oriented and other-oriented lies. **Self-oriented lies** serve the liars interests by protecting him psychologically (e.g., protecting him from embarrassment) and advantage his personal interests (e.g., protect him from physical punishment). **Other-oriented lies** are told to protect or advantage someone else's interests. (cf. DePaulo et al., 1996, p. 983) Similar to benign and exploitive lies, other-oriented lies receive more social acceptance than self-oriented lies, because the intention behind an other-oriented lie is considered as an expression of concern for the feelings and interest of other people. (cf. Bryant, 2008, p. 25f.)

Some lies are considered to be less severe than others – such as benign lies or other-oriented lies. These sorts of lies are commonly known as white lies. A white lie is an untruth of little moral value that is not meant to harm anyone. (cf. Bok, 1978, p. 58; cf. Bryant, 2008, p. 26)

White lies indicate, that people are motivated to use these kinds of lies to avoid tension or conflict – which could harm either person’s pride or image – and thus preserve interpersonal relationships. (cf. Edgley, Olmstead and Turner, 1975, p. 77; cf. Bryant, 2008, p. 26) In order to do so, people are willing to conceal or falsify information. (cf. Ekman, 2001, p. 28f.) The use of white lies is so common and widely accepted that they are not considered lying, on the contrary they may serve as “social lubricant”(Saxe, 1991, p. 414) due to their intention to avoid harm. (cf. Bryant, 2008, p. 26)

Regarding the research question “How do college students define white lies and distinguish them from other forms of deception?” (Bryant, 2008, p. 27), Bryant has conducted interviews with students at a large university. Through his study Bryant identified three main types of lies (real lies, white lies, and gray lies) that are categorized based on five factors (intention, consequences, beneficiary, truthfulness, and acceptability of the lie), as shown in Table 1. (cf. Bryant, 2008, p. 27f.)

| Types of Lies | Factors               |                                                                                                                               |                                                                                                        |                                                                                                                                  |                                                                                                                                                      |                                                                                                                           |
|---------------|-----------------------|-------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|
|               |                       | Intention                                                                                                                     | Consequences                                                                                           | Beneficiary                                                                                                                      | Truthfulness                                                                                                                                         | Acceptability                                                                                                             |
|               | Real Lies             | <ul style="list-style-type: none"> <li>• Malicious</li> <li>• Deliberate</li> <li>• Deceptive</li> <li>• Deceitful</li> </ul> | <ul style="list-style-type: none"> <li>• Serious</li> <li>• Direct</li> </ul>                          | <ul style="list-style-type: none"> <li>• Self-Serving</li> <li>• Egotistical</li> </ul>                                          | <ul style="list-style-type: none"> <li>• Complete Fabrication</li> <li>• Blatant Untruth</li> <li>• Zero Truth</li> </ul>                            | <ul style="list-style-type: none"> <li>• Unacceptable</li> <li>• Not Justified</li> </ul>                                 |
|               | White Lies            | <ul style="list-style-type: none"> <li>• Benign</li> <li>• Pure</li> </ul>                                                    | <ul style="list-style-type: none"> <li>• Trivial</li> <li>• Meaningless</li> <li>• Harmless</li> </ul> | <ul style="list-style-type: none"> <li>• Altruistic</li> <li>• Other-Focused</li> <li>• Protecting</li> <li>• Helpful</li> </ul> | <ul style="list-style-type: none"> <li>• Partial Truth</li> <li>• Half Truth</li> <li>• Bending the Truth</li> <li>• Stretching the Truth</li> </ul> | <ul style="list-style-type: none"> <li>• Acceptable</li> <li>• Justified</li> <li>• Expected</li> <li>• Common</li> </ul> |
|               | Gray Lies             |                                                                                                                               |                                                                                                        |                                                                                                                                  |                                                                                                                                                      |                                                                                                                           |
|               | Ambiguous Gray Lies   | <ul style="list-style-type: none"> <li>• Ambiguous Intention</li> </ul>                                                       | <ul style="list-style-type: none"> <li>• Ambiguous Consequences</li> </ul>                             | <ul style="list-style-type: none"> <li>• Ambiguous Beneficiary</li> </ul>                                                        | <ul style="list-style-type: none"> <li>• Ambiguous Level of Truth</li> </ul>                                                                         | <ul style="list-style-type: none"> <li>• Open to Interpretation</li> </ul>                                                |
|               | Justifiable Gray Lies | <ul style="list-style-type: none"> <li>• Malicious</li> </ul>                                                                 | <ul style="list-style-type: none"> <li>• Direct</li> </ul>                                             | <ul style="list-style-type: none"> <li>• Self-Serving</li> </ul>                                                                 | <ul style="list-style-type: none"> <li>• Complete Fabrication</li> </ul>                                                                             | <ul style="list-style-type: none"> <li>• Justified</li> <li>• Acceptable</li> </ul>                                       |

Table 1: Categorization of Lies (own illustration, cf. Bryant, 2008, p. 32)

Similar to the definition of outright and self-oriented lies, the participants of Bryant's study agreed that **real lies** are complete fabrications and contain no true information. They are considered to be malicious, and their purpose is self-serving and egotistical. Therefore, most participants define real lies as nonacceptable and suppose serious consequences to real lies. (cf. Bryant, 2008, p. 32)

In Bryant's study a **white lie's** intention is described to lack malicious intent and was clearly categorized by benignity. Furthermore, the consequences of a white lie are classified as harmless and trivial, because the beneficiary purpose of the lie is of altruistic nature. Since white lies are described as partial truths, omissions, or exaggerations, most students agree that white lies are considered as acceptable, in some cases even expected behavior, in order to protect someone else from harm (cf. Bryant, 2008, p. 35f.)

**Gray lies** build the last category of lies, that surfaces from Bryant's study. Other than real and white lies, gray lies do not possess clear boundaries. Gray lies are described as not as serious enough to be considered real lies, yet too serious to be white lies. Due to this, gray lies are split into two categories: (1) ambiguous gray lies, and (2) justifiable gray lies.

Ambiguous gray lies are heavily dependent on interpretation. They can be put both in the real lie and the white lie category, depending on how one looks at it. An **ambiguous gray lie** could be a complete fabrication of the truth but could protect someone from being harmed. According to the truthfulness factor of the lie it would be considered a real lie, but when looking at the beneficiary factor, the lie would be classified as white lie. This ambiguity places this type of lie into the gray area of lying.

Another major factor of gray lies is their acceptability. Even though the lie fulfills all the attributes of a real lie (self-serving, purposely deceitful, direct consequences, and complete fabrication of the truth) some gray lies are accepted as they are justifiable under certain circumstances. These lies are called **justifiable gray lies**. Basically, justifiable gray lies are real lies whose use is widely accepted. The participants of Bryant's study agreed, that the use of these kinds of lies is justified, when it can protect one-self and others from harm that could occur if the truth were to emerge (cf. Bryant, 2008, p. 36f.)

## 2.3 Non-verbal Lie Detection

One of the most influential researchers in the field of nonverbal behavior is Paul Ekman. Paul Ekman, born in 1934, is an American psychologist and professor, renowned for his pioneering work on the development and expression of emotions as well as their link to facial expressions. As a co-discoverer of micro expressions, he is a leading expert in the field of deception and is working as lie expert for the FBI and CIA. In 1991 the American Psychological Association has awarded Ekman with the Distinguished Scientific Contribution Award for his contributions to the psychological research. (cf. Practical Psychology, 2022; cf. Rowohlt, no date) Due to its impact to the scientific discourse, Ekman's definition, and elaborations on nonverbal behavior in the context of lying and deceit build the groundwork of this thesis.

In his book *Telling Lies*, Paul Ekman defined lying as "a deliberate choice to mislead a target without giving any notification of the intent to do so"(Ekman, 2001, p. 41). Meaning that the liar is able to choose between lying and telling the truth and knows the difference between the two options. A liar always misleads his victims on purpose, without any prior notification to and invitation from the victim to do so.(cf. Ekman, 2001, p. 26f.)

When lying, Ekman differentiates between two major kinds of lying: (1) concealment and (2) falsification. Withholding some true information while not telling anything untrue, is considered **concealment**. According to Ekman, since nothing untrue is being told, most of the people do not consider concealment as lying, making it easier for the liar to get away with his lie. But in contrast to concealment, **falsification** is considered lying by most of the people, because falsifying is adding an additional step to concealment: The liar does not only withhold some true information but presents false information as if it were true. (cf. Ekman, 2001, p. 28) Falsification is often used, when the truth that is being concealed, needs to be masked to cover the truth. This phenomenon becomes more prominently visible when (true) emotions need to be concealed: The stronger the true emotion the harder it is to conceal. Only falsifying a false emotion, one that is not truly felt, can cover the true emotion, and protect it from leakage. (cf. Ekman, 2001, p. 31f.) This marks one of two ways in which emotions become involved in lying and deception: the main aim of the lie being the concealment or fabrication of an emotion. But even if a lie is about a non-emotional matter, emotions can become involved when the stakes of the lie are high. This includes the fear of being caught, feeling guilt about lying (especially, if the liar and receiver of the lie share the value of honesty), or if

misleading the target is viewed as challenge, whose success is appreciated by a present audience (duping delight). (cf. Ekman, 1988, p. 166; cf. Ekman et al., 1991, p. 134) For Ekman lies fail for two reasons: The liar either fails to thoroughly prepare for lying or emotions interfere with his or her performance. (cf. Ekman, 1988, p. 164)

According to Ekman, lying and emotions are linked, as they make the concealment or falsification of the truth visible. The question that arises from here is, what classifies an emotion and if it differs from, how does it differ from lying? Is lying an emotion or rather behavior caused by emotions?

As there is not one uniform definition of emotion, the following subsection discusses multiple emotion theories attempting to classify emotions, identify their causes, and analyze their effects on human behavior.

## 2.4 Emotion theories

The difficulty in defining emotion lies in the complexity of emotional processes and conditions. This complexity allows to analyze emotion from many different standpoints. The main emotion theories can be grouped in seven approaches:

- (1) **Psychobiological & sociobiological approach** – Sociobiology analyzes behavioral characteristics of emotion responsible for social behavior from humans and mammals in context of biological fitness. Aim of psychobiology is to reach concrete descriptions of human and animal behavior, by identifying its causes and development, and eventually give precise predictions of behavioral effects. (cf. Spektrum, 2000a, cf. 2000b)
- (2) **Psychophysiological approach** - analyzes human behavior with emphasis on the connection of mental and physical processes of the human body. (cf. Villasante, 2022)
- (3) **Psychoanalytical approach** – analyzes the effects of unconscious mental processes on human behavior. (cf. Mertens, 2000)
- (4) **Learning theoretical approach** – analyzes changes in human behavior, which is not caused by innate processes or processes of maturation. (cf. paulekman.com, 2024)
- (5) **Cognitive theoretical approach** – analyzes mental processes to evaluate how information from the outside world is processed and which reactions and emotions are triggered by them. (cf. Mcleod, 2023a)

(6) **Attribution theoretical approach** – analyzes the effect of causal explanations (= attributions) that people make regarding their own behavior and certain events in their environment, on human behavior. (cf. Haeckel, 1999)

(7) **Developmental-psychological approach** – analyzes the changes of human behavior, thinking, and feeling throughout a lifespan. (cf. Mcleod, 2023b)

If emotions, as Ekman claims, interfere with the liar's emotions making a lie visible, the following aspects of emotion need clarification:

- (1) Are emotions learned or innate?
- (2) Can emotions be controlled by an individual?
- (3) How do emotions develop inside an individual? Can they be manipulated or even suppressed at some point in the process?

In order to answer these questions, the following subsections briefly introduce the individual approaches and highlight their main characteristics.

#### **2.4.1 Psychobiological and sociobiological approaches**

The psychobiological and sociobiological theory on emotion follows the Darwinian research approach and discusses the contribution of emotional reaction systems on the comprehensive biological fitness and reproductive success. (cf. Birbaumer, 1983, p. 37) According to Darwin the function of emotional expression is the enabling of cooperation through communication of affective reactions and the associated intentions to act between members of a community. This includes the clarification of rank disputes within the group and is beneficial for all social species. Consequently, before every form of communication with conspecifics, emotions have an independent behavior-controlling as well as an activating effect. The psychobiological and sociobiological approach assumes that meaningful behavioral goals, which aim to guarantee reproductive success, are achieved through emotions by pleasure and displeasure mechanisms and the instrumental learning made possible by them. (cf. Birbaumer, 1983, p. 39ff.)

Basic emotional reaction systems and the correlating behaviors, such as fear, anger, and sexual arousal, can be found not only in humans, but also in non-human primates and high developed mammals. Furthermore, comparable brain areas, particularly the amygdala, are involved in the forming of emotional reactions in humans as well as other mammals. These arguments

indicate, that basic emotions do have a biological origin and are to some extent comparable among humans and other mammals.(cf. Birbaumer, 1983, p. 38f.)

## 2.4.2 Psychophysiological approach

The development of the psychophysiological approaches is characterized by two opposing findings of William James and Carl Lange, and Walter Cannon.

Following Lange's findings, James states that fully developed feelings require feedback from peripheral expressions of feelings to the central nervous system (CNS), meaning that for the full experience of emotion a sensation of the internal organs and/or muscles is necessary.(cf. Birbaumer, 1983, p. 45; cf. Kalat and Shiota, 2018, p. 8f.) This theory is commonly known as the **James-Lange theory** and its statement regarding the feeling of an emotion can be summarized as follows:

Event → Cognition/Appraisal → Physiological Changes & Behavior → Emotion

*Figure 1: James-Lange theory (own illustration, cf. Kalat and Shiota, 2018, p. 9)*

According to the James-Lange theory emotion is the feeling of physiological changes as they occur. (cf. Cannon, 1987, p. 568)

Walter Cannon and other neurophysiologists on the other hand emphasize the central nervous origin of emotions. According to Cannon the responses of muscles and organs are too slow to cause the feeling of emotion. Around Cannon's findings a new theory is formulated – the **Cannon-Bard theory** – stating that emotions are causally independent of physiological changes and behavior, even though they all occur at the same time.(cf. Birbaumer, 1983, p. 45; cf. Cannon, 1987, p. 574; cf. Kalat and Shiota, 2018, p. 9) The Cannon-Bard theory can be depicted as follows:

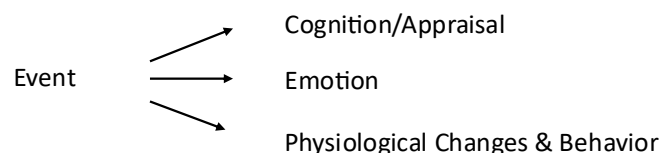


*Figure 2: Cannon-Bard Theory (own illustration, cf. Kalat and Shiota, 2018, p. 10)*

In summary it can be said that the psychophysiological approach of emotions is based on the following assumptions:

1. Emotional processes are linked to the functionality of vegetative-autonomous and central nervous structures.
2. Different emotions correlate with distinctive patterns of central nervous-vegetative-muscular processes.
3. Deliberate, cognitive assessment mechanisms can influence the quality and intensity of emotions but are not a necessity for the development of emotions.
4. An essential prerequisite for the development of differentiable emotions is the feedback of somatic-muscular and vegetative changes in central nervous structures.
5. Basic emotions are innate and genetically imprinted physiological patterns as reaction to some specific stimuli.(cf. Birbaumer, 1983, p. 50f.)

Similar to the psycho- and sociobiological approach, the psychophysiological approach grants emotion a behavior controlling and activating effect. Both approaches see emotion as rather unconscious and influenced by physiological changes in the body to external stimuli. The approaches also agree in terms of the biological predisposition of basic emotions and the principle of instrumental learning.

#### **2.4.3 Psychoanalytical approach**

Psychoanalysis is interested in the unconscious mental processes, which occur between the phase of recognition of an emotion causing impulse and the subsequent behavior. Sigmund Freud's drive theory nowadays is considered pre-scientific, due to the use of not clearly differentiable scientific, physiological, and psychological terms. Nevertheless, his following assumptions are constructive approaches on a psychoanalytical emotion theory:

1. Emotions are always related to the subject (oneself) as well as to another object.
2. Emotions undergo a development, progressing from premature to mature stages.
3. Emotions are unconscious. Humans are rather controlled by their emotions than cognitively controlling the emotions primarily.
4. Emotions are often in conflict with human control instances and are thereby changed. Meaning that suppression mechanisms can change emotions secondarily but cannot prevent them from occurring.
5. Emotions affect both mental and physical phenomena.
6. Emotions are evidence for ambivalence, meaning the existing of two contradicting emotions towards one and the same person. (cf. Kutter, 1983, p. 53f.)

Based on Freud's theory, George Klein formulates a more modern, motivation theoretical approach of the psychoanalytical emotion theory. Klein's theory states that repressed emotions can come to life again with great intensity and freshness after overcoming resistance during the analytical process. The corresponding phantasies form a cognitive-emotional-motoric unit with emotion and behavior. This unit can be influenced by external stimuli and are therefore prone to suppression, but the unit always remains as coherent pattern and maintains its direction and intensity. The unit is equivalent to a program of lived experience and the associated emotional actions and dispositions. (cf. Kutter, 1983, p. 54)

Following the already mentioned approaches, De Rivera formulated a structure theory of emotions. According to him, emotions can be differentiated into three sets (love/anger, appreciation/contempt, acceptance/rejection) moving around three dimensions: being, belonging, and recognition. Depending on the person the emotion is aimed at, six types of emotions can occur:

1. Love, appreciation, acceptance (moving towards the person)
2. Anger, contempt, rejection (moving away from the person) (cf. De Rivera, 1977, p. 40ff., 107ff.; cf. Kutter, 1983, p. 56)

When trying to formulate one unified definition of a psychoanalytical emotion theory, all the previously mentioned approaches are considered, depending on the observed phenomenon. All in all, the psychoanalytical approach agrees on the equal significance of felt emotion, cognition, and interaction. (cf. Kutter, 1983, p. 56f.)

Whereas the psychoanalytical approach too grants emotion an unconscious role, it also highlights the equal significance of cognitive evaluation of the (emotional) arousal. Contradicting to the previously mentioned approaches, emotion is not caused only due to physiological changes in the body to external stimuli, but more on the mental processing of these. Emotion therefore is highly dependent on individual experience, judgement and thinking. In contrast to the psycho- and sociobiological as well as the psychophysiological approach, it does not see the biological predisposition, but personal experience and learned emotion-behavior patterns as decisive for emotional behavior.

#### **2.4.4 Learning-theoretical approaches**

Learning theory (behaviorist) approaches analyze emotional behavior in its dependence on external, environmental events. Unlike the psychoanalytic approach, for the behaviorist approach internal structures or processes play no role in explaining emotions as internal states. In the behavioristic approach, emotional behavior is rather a function of external stimuli. The crucial explanation process for the emergence of emotional behavior is considered to be learning, which is understood as a change in behavior based on experience. The behavioristic approach can be divided into four subgroups (classic behaviorism, radical behaviorism, neo-behaviorism, cognitive behaviorism) that are elaborated further below.

Characteristic for the classic behaviorism is the differentiation of emotions based on situational conditions. The classic behaviorism is strictly anti-mentalist, meaning that inner states of consciousness are not considered as the cause of behavior.(cf. Euler, 1983, p. 62f.)

Comparable to the classic behaviorism the radical behaviorism takes an anti-mentalist position as well. In radical behaviorism emotions do not have a behavioral use. Therefore, radical behaviorism focusses on two aspects: emotional behavior (physiological, expressive, and motoric reactions) and changeable environmental conditions (consequences of behavior and their cues) controlling this behavior. In radical behaviorism operant conditioning plays an important role. The operant conditioning is also known as instrumental learning because the behavior is the instrument for producing the subsequent consequence. Radical behaviorism believes that instrumental behavior is only gradually learned through frequently recurring, uniform consequences. (cf. Euler, 1983, p. 64; cf. Edelman, 2000)

Emotions are only regarded if they result from or influence instrumental behavior. Emotions and reinforcement are intertwined in two ways. One, emotions are by-products of reinforcement plans: For example, anger, usually recorded as "aggressive behavior", results from a sudden and drastic reduction of density in (positive) reinforcement. And two, emotions influence the effect of various other enhancers – e.g., a fear-provoking situation is also characterized by the fact, that several possible environmental enhancers become ineffective.(cf. Euler, 1983, p. 64f.)

Neobehaviorism in the other hand conceptualizes emotions as intervening variable – conditions that are interposing between stimulus and reaction. As such, emotions are thought

to relate the various stimuli- and reaction-events and increase the predictive power of behavioral patterns.(cf. Euler, 1983, p. 65)

Other than in all the other sub-approaches in learn theory, the cognitive behaviorism explicitly acknowledges intermediary (cognitive) processes, such as expectations or personal assessments, and grants them theoretical independence. Behavior is no longer seen as exclusively determined by the previous stimulus situation and/or the consequences of behavior, but rather as determined by the situation or the consequence of behavior as perceived by the individual. With the final departure from anti-mentalism, cognitive behaviorism enables the rehabilitation of emotions in the learn theory approach. (cf. Euler, 1983, p. 68)

Due to its strict anti-mentalist approach classical learn theory does not contribute as many insights on emotion theory as other approaches. Only the cognitive behaviorism loosens up the tight corset of instrumental learning and considers cognitive processes to result in individual differences in experiencing emotion. As learn theory sees emotion rather as a function than an innate or unconscious reaction pattern, it does not relate to any previously mentioned emotion theory approaches.

#### **2.4.5 Cognitive-theoretical approaches**

**Cognitive theory approaches** ascribe cognitive processes in the development of emotions a key function. Here, perception, imagination, memory, thinking and speaking in the context of action are central cognitive subprocesses of human information processing. Cognitive subprocesses, which can also lead to emotion, share the following attributes:

- They take place in the human organism and cannot be reduced to external stimulus constellations.
- They represent objects, processes, or states.
- They select from the available information and construct cognitive structures.
- They occur with the active participation of the person.
- They can replace external stimuli for action.
- They are phenomena of an organized system.

In principle, the cognitive-theoretical approach views emotions as consequences of cognitive analyses.

A prominent cognitive emotion theory is formulated by **Lazarus, Kanner and Folkman**. According to their theory, emotions are constructed by the relationship of a person to its environment through cognitive processes (person-environment-transactions). According to this approach, emotions are the result of cognitive mediated transactions with the actual, imagined, or anticipated environment. Emotion is defined as a complex and organized state, consisting of cognitive appraisal, impulse to act and physiological reactions. If one of these three attributes is not experienced no real emotion is felt. Cognitive appraisal is differentiated in individual assessments of the situation (primary appraisal), the options for action (secondary appraisal) and the perceived changes because of one's own reaction and repercussions from the environment (new appraisal). The impulse to act embodies the willingness to act which is not necessarily executed or visible – the impulse can be suppressed, denied, or transformed. Furthermore, every feeling of a certain profile is connected to distinct physiological reactions. At the same time, this theory includes a social component to its definition: As personal appraisal is highly dependent on socially mediated norms, they influence the assessments of situations and emotions therefore also become social constructions. (as cited in cf. Mandl, 1983, p. 75f.)

As the name indicates, the cognitive-theoretical approach considers cognitive(sub-)processes to be responsible for emotion. Depending on how an individual assesses a certain situation, different emotions can be triggered. Compared to the other already mentioned approaches, in the cognitive-theoretical approach states that to experience a true emotion, all cognitive appraisal, impulse to act, and physiological reactions need to occur. So, emotional behavior is not solely dependent on external stimuli anymore. Similar to the learning theoretical approach, emotional behavior can be triggered based on (learned) experience and social norms of an individual – making emotional behavior highly dependent on factors such as culture, upbringing and moral.

#### **2.4.6 Attribution-theoretical approaches**

**Attribution-theoretical approaches** are a variant of the cognitive-theoretical approaches within emotion psychology. In this approach, causal explanations (= **attributions**) that people

make regarding their own behavior and certain events in their environment, take on a central role. The main hypothesis in this approach is that the quality of emotions is dependent on these attributions. Emotions are often described as complex reaction syndromes that include physiological changes (e.g., release of hormones), expressive responses (e.g., pupil dilation), subjective experience (e.g., love), and instrumental responses (e.g., flight). Attribution theoretical approaches deal with the subjective experience of emotions and their effect on behavior.

One of the most prominent theories in this field is the **Two-Factor-Theory of Emotion** by **Schachter and Singer** introduced in 1962. It states that emotions are based on the interaction of (1) physiological arousal and (2) cognition. The arousal itself is emotion-unspecific but its extent determines the strength of an emotion. Cognition on the other hand decides which emotion arises. In this way, the same form of arousal can be experienced as a different emotion depending on the cognition. Cognition in this context is assumed to be a cognitive evaluation of the causes of the state of arousal and interpretation of the situation based on that knowledge. Together the arousal and the cognition shape the felt emotion. (as cited in cf. Kasten, 1983, p. 80ff.)

Being a variant of the cognitive-theoretical approach, the attribution-theoretical approach overlaps with the cognitive-theoretical approach. Both view cognitive processes as decisive for emotion. The arousal itself does not specify which emotion is felt, but rather the cognition (attribution). So, similar to the cognitive-theoretical approach, the feeling of emotion and their intensity varies highly between individuals.

#### **2.4.7 Developmental-psychological approaches**

**Developmental-psychological approaches** of emotion theory deal with the ontogenetical<sup>1</sup> development of emotions. Jean Piaget and his organismic development theory contributes to the psychological research in the field of developmental-psychological emotion theory to a large extent. **Jean Piaget** assigns emotion an energetic and cognition a structural role, whose ontogenesis obeys the fundamental principles of accommodation and assimilation<sup>2</sup>. The

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<sup>1</sup> Individual biological/evolutionary development of organisms. (cf. Haeckel, 1999)

<sup>2</sup> Accommodation is the adaption of an individual to its environment. Assimilation on the other hand describes the change in the environment through the individual. (cf. Niemann, 2003)

imbalance between accommodation and assimilation awards emotion its energetic power that cognition navigates in structure and direction. Throughout the ontogenesis of the organism different cognitive-structural patterns and typical emotions can be identified that determine how the individual deals with different environments, objects, and persons. Piaget's research also emphasizes a tendential primacy of cognition. This means that cognitive development is at most accelerated or delayed by emotional-affective energies, but not structurally influenced or changed by them. (as cited in Kasten, 1983, p. 85f.)

Another researcher to mention in this context is **Carroll Izard**. He assumes that there are innate neural arousal patterns for ten basic discrete emotions (anger, contempt, shame, fear, guilt, distress, disgust, joy, interest, surprise), which are universal across almost all cultures. (cf. Izard, 2013, p. 4ff.,83ff.) The ontogenetic development of the ten basic emotions is primarily a function of maturity processes and secondary a function of environmental influences and the cognitive processing of these. Izard emphasizes the two-way interaction of cognition and emotion: perception and cognition can influence emotion (e.g., through suppression) but emotion can also affect the perception and cognition. According to Izard all innate basic discrete emotions can be learned to be inhibited. (cf. Izard, 2013, p. 5f.) Emotions represents one of six subsystems constituting the personality of an individual. Besides emotions, the subsystems include the homeostasis-, instinct-, perception-, cognition-, and motor system. The interaction between the subsystems forms four classes of motivation: (1) Instincts, (2) Emotions, (3) current affective-perceptual and affective-cognitive interactions, and (4) lasting affective-cognitive structures. (as cited in cf. Kasten, 1983, p. 89ff.)

The developmental-psychological approach has similarities to the cognitive and attribution theoretical approaches. They all see cognition as decisive for emotion. But the developmental approach sees the development of emotion as a pure maturity process throughout human development. The emotions are innate and learned through the fundamental principles of assimilation and accommodation.

The mentioned emotion theories vary in the aspect of autonomy of emotions. Whereas some emotion theories argue that emotions are innate, autonomous reactions to external stimuli, others argue that cognition does interfere in the process of emotion. The theories also disagree in terms of the degree to which cognition interferes with emotion and at what point in the process. Some say emotions can be suppressed or directed through cognitive processes,

others say that emotions are learned patterns – either through instrumental learning or through personal experience. Others say that emotion develop among an innate maturity axis. To conclude, the previous section confirms the complexity and difficulty of formulating one unified definition of emotion. The section shows that emotion has many different perspectives and research directions.

## **2.5 Non-Verbal Indicators for Emotion**

Research has shown that especially facial expressions deliver significant cues to the emotional state of humans.(cf. Porter, Ten Brinke and Wallace, 2012, p. 24) Charles Darwin was one of the first who has analyzed the expression of emotion in humans and animals. In 1872 already, Darwin hypothesized that certain facial expressions cannot be made voluntarily but can occur involuntarily when genuine emotion is felt (cf. Porter and Ten Brinke, 2008, p. 509): “A man when moderately angry, or even when enraged, may command the movements of his body, but (...) those muscles of the face which are least obedient to the will, will sometimes alone betray a slight and passing emotion.(Darwin, 1948, p. 28)”

Leaning on Darwin’s theory and observations, Ekman focuses his research on the facial expressions of humans and the revelations they contain regarding true felt emotions, rather than portrayed emotions on the face. According to him true felt expressions of emotion occur because facial movements can be produced involuntarily, without intention. The false expressions on the other hand occur because there is also voluntary control of certain muscles in the face that allows people to interfere with the felt emotion and produce a false expression of emotion on the face. (cf. Ekman, 2001, p. 123f.)

There is a common ground between voluntary and involuntary facial expressions: they are both once learned. Corresponding with the psychobiological and sociobiological approaches in emotion theory, Ekman states that the involuntary expressions of the face are the result of evolution, as many human expressions can also be observed on the faces of other primates. Some of the expressions of emotion (happiness, fear, anger, disgust, sadness, contempt, and surprise) are universal regardless of sex, age, or culture. The voluntary facial expressions on the other hand are learned within the first few years of life. Children learn display rules based on social and cultural norms and conventions and consequently learn when and to whom to show and to conceal their true feelings and to falsify expressions of emotion that are not felt.

(cf. Ekman, 2001, p. 125) Once learned, these display rules function as habits, that people do not think about unless they find themselves in unfamiliar circumstances or have made a mistake. (cf. Ekman and Friesen, 2003, p. 138)

According to Ekman there is a variety of facial expressions and not all of them are involved with emotion. He differentiates between conversational signals, facial emblems, facial manipulators, and emotional expressions. **Conversational signals** are used to emphasize speech or to provide syntax in a conversation. (cf. Ekman, 2001, p. 127) **Facial emblems** (e.g., one-eye closure wink) are defined as “acts (a) which have a direct verbal translation usually consisting of a word or two, or a phrase. (B) ...this precise meaning is known by most or all members of a group, class, subculture, or culture (c) which are most often deliberately used with the conscious intent to send a particular message to other person(s), (d) for which the person(s) who sees the emblem usually not only knows the emblem’s message but also knows that it was deliberately sent to him, and (e) for which the sender usually takes responsibility for having made that communication. (Ekman, 1976, p. 14)”. **Facial manipulators**, such as lip biting and lip sucking, are movements of the face, that manipulate another part of the face in some kind of way. Many of these facial manipulators seem to have no instrumental goal, other than reassurance or comforting, but according to Ekman most of them are simply reflections of nervousity and habitual activity. (cf. Ekman, 2004, p. 43) Lastly, **emotional expressions** are involuntary signals, that have been refined and selected over the course of evolution to provide important information to others in the context of social communication. Such expressions serve as indicators to others that and which emotion is occurring.(cf. Ekman, 2004, p. 44f.)

## 2.6 Connection between Emotion and Lying in Non-Verbal Lie Detection

Ekman’s approach and his theory on facial expressions play an important role in lie and lie detection research. Besides other indicators such as body language and physiological changes in the body, facial expressions are often investigated to reveal the cues to deceit. Since Ekman’s theory on facial expressions in the context of lying is most commonly used as groundwork for many research papers on nonverbal cues to deceit, his hypothesis is elaborated further in the following section.

According to Ekman and Friesen, people are less practiced in controlling their facial expressions than they are in controlling their words. Whereas words can be monitored, inhibited, or falsified better, facial expressions seem to reveal how someone truly feels. But since people are taught display rules to control their facial expressions, some involuntary facial responses can be altered to hide the true emotion felt. For that reason, Ekman and Friesen assume facial expressions to be more truthful than words. (cf. Ekman and Friesen, 2003, p. 137)

As stated by Ekman and Friesen, there are four reasons why people control their facial expressions:

1. Following display rules to maintain social role.
2. Following personal display rule-habits that result from deeply ingrained conventions (cultural display rules) and/or the individual upbringing, experience, character, and family idiosyncrasies (personal display rules). (e.g., “poker face”, or subservient expressions towards authorities)
3. Following vocational requirements (e.g., actors, attorneys, and diplomats)
4. The need of the moment to protect oneself and save face (e.g., in a testimony). (cf. Ekman and Friesen, 2003, p. 138f.)

Furthermore, Ekman and Friesen identify three techniques of facial management: (1) to qualify the appearance of the truly felt emotion, (2) to modulate the expression of the felt emotion, or (3) to falsify the expression of the felt emotion. (cf. Ekman and Friesen, 2003, p. 140)

### **2.6.1 Micro expressions as source of leakage (Ekman’s approach)**

Ekman introduces micro expression as the most tantalizing source of facial leakage. Micro expressions belong to the group of emotional expressions. They provide a full picture of the true felt emotion, that is being concealed while lying. As a micro expression appears and disappears on the face in less than a quarter of a second, it is barely recognizable and usually missed by the observer. As information rich as they are, they do not occur very often. Instead, squelched expressions are visible on the face once a person is concealing an emotion. Squelched expressions are interrupted micro expressions occurring once the person becomes aware of which emotion is beginning to show on its face and therefore interrupts and sometimes covers the emerging expression with another one. A squelched expression may be

interrupted, but it lasts longer than a micro expression, making the concealment of emotion more noticeable. Even though the squelch does not always deliver the real emotion that is being concealed, its occurrence alone can be a valuable cue that the person is concealing an emotion. (cf. Ekman, 2001, p. 129ff.)

According to Ekman not all facial muscles are equally controllable. Reliable muscles are facial muscles that cannot be easily controlled and therefore not used for an intentionally false expression. Therefore, expressions involving these reliable muscles are more difficult to inhibit or squelch. (cf. Ekman, 2001, p. 132) For example, expressions of sadness, fear, and worry. (cf. Ekman, 2001, p. 134)

Ekman claims that the clues to deceit can be found in micro expressions, expressions visible before a squelch, and/or the remaining expression on the face due to the involvement of reliable facial muscles leading to a failure to inhibit the felt emotion. (cf. Ekman, 2001, p. 140f.)

Based on years of research Ekman and Friesen first introduced the Facial Action Coding System (FACS) in 1978. Revised in 2002, the FACS constitutes a system to comprehensively describe all visually distinguishable facial movements. To do so, facial expressions are decomposed into individual components of facial muscle movements. These components are called Action Units (AUs). The FACS serves as guide for trained individuals to categorize facial movements and expressions, based on the triggered AUs. To summarize, the FACS defines facial movements and expressions by grouping individual muscle movements (AUs) together. Multiple AUs then constitute one facial expression. (cf. Ellgring, 1987, p. 894; cf. Ekman and Friesen, 2003, p. 207; cf. paulekman.com, 2024)

## **2.7 Current State of Research on Non-Verbal Lie Detection**

The current state of research provides arguments for and against non-verbal lie detection. A major argument against non-verbal lie detection is most psychological studies consent that non-verbal behavior is not a sufficient indicator for deceptive behavior. On the contrary, the studies reviewed by a meta-analysis by DePaulo and Bond, come to the conclusion, that verbal (audible) clues lead to significantly higher lie detection abilities of human judges. (cf. Bond and DePaulo, 2006, p. 217; cf. Khan et al., 2021, p. 2) When evaluating the accuracy of truth-classification, the observers' ability to correctly classify truth tellers lays at 63.38%, when only hearing a target person. When the observer is only seeing the target person, just 52.16% of

truth tellers are correctly classified. In audiovisual settings (when the observer could both hear and see the target person) 56.20 % of truth tellers were correctly classified. Looking at these findings alone, it can be derived that adding audible clues the accuracy of correct truth teller detection increases by 4.04%.

An interesting finding of the meta-analysis of Bond and DePaulo is that in terms of correct Lie-Truth Classifications, the accuracy rates of correct classifications of truth and lie tellers through video, audio and audiovisual clues are moving closer together: With 50.35% the accuracy rate of correct classification of truth and lie tellers when only observing video clues is still the lowest of all three categories. But the percentual difference in accuracy between the three categories is decreasing. The accuracy rate of correct truth and lie classifications when only hearing the target person lies at 53.75%. But if the observer can both see and hear the target person the accuracy rate even increases to 53.98%. Meaning that audiovisual clues generate the highest accuracy rates when it comes to classifying truth and lie tellers correctly. So, the statement about audible clues leading to significantly higher lie detection ability is only partially true: If looking at accuracy rates for correct truth classifications only, then audible clues seem to be more reliable. But this measure also implies that in a set of truths and lies told, the accuracy of truths being correctly classified may be high, but this does not mean that lie detection is better. Lies can also be falsely classified as truths but are not included in the accuracy rate. Therefore, the accuracy of the correct lie-truth classifications is more significant for the study at hand. Derived from that, it can be concluded that a combination of both verbal and non-verbal clues result in the highest accuracy rates for correct lie and truth classifications by an observer. (cf. Bond and DePaulo, 2006, p. 225f.; cf. Vrij and Fisher, 2020, p. 5)

Another finding is that lying is cognitively more demanding than telling the truth. This increase in cognitive load could result in verbal and non-verbal clues that reveal a liar: A liar not only needs to make up a story, but also control any upcoming behavioral clues that may expose the lie. Additionally, the liar must constantly monitor the observer's reactions and make sure, that the fabricated story remains consistent and conclusive. A liar may also be more involved in his or her narrative than a truth teller, going into further detail. This also increases the level of uncertainty transported through their elaborations. Furthermore, liars tend to make more movements than truth tellers, when put on the spot and telling their story in reverse order. This indicates, that liars are more nervous, when they have to deviate from their prepared

narrative. (cf. DePaulo et al., 2003, p. 102f.; cf. Vrij et al., 2008, pp. 254, 262; cf. Van Bockstaele et al., 2012, p. 1)

A study by Marchak mentions the importance of eye interactions (blink rate, count, and duration) for lie detection. Marchak finds out that participants with false intent showed a shorter maximum blink duration as well as fewer numbers of blinks. (cf. Marchak, 2013, p. 7) Khan et. al. conclude that eye movements are even more distinctive for deceptive and truthful behavior than facial micro-movements. (cf. Khan et al., 2021, p. 11)

An artificial neural network (ANN) trained to classify truthful and deceptive behavior by O'Shea et al. also proves non-verbal clues to be important within automated lie detection. The ANN is trained with video data collected in a training experiment (containing eye data, face data, and face angle data) and measured the importance of individual non-verbal attributes (such as eye blinks and movements, and head and face movements). The ANN achieves an overall accuracy rate of 75.55% for truthful classifications and 73.66% for deceptive classifications. O'Shea et al. even expect the accuracy rate to increase, once more data is captured and provided to the ANN. (cf. O'Shea et al., 2018, p. 4ff.; cf. Khan et al., 2021, p. 2f., 6f.) When it comes to Ekman's most tantalizing source of leakage, micro-expressions, there is no evidence that micro expressions distinguish between truth tellers and liars. (cf. Burgoon, 2018, p. 4; cf. Vrij and Fisher, 2020, p. 5)

Even if the results seem to differ, a certain consensus can still be seen: No individual feature of non-verbal behavior functions as reliable indicator for deceptive behavior. It is rather a combination of non-verbal features occurring at the same time interval, that could provide more meaningful indicators for deception. (cf. DePaulo et al., 2003, p. 104; cf. O'Shea et al., 2018, p. 3; cf. Vrij and Fisher, 2020, p. 5)

At this point another study is important to mention, as it functions as inspiration for the conducted experiment of the study at hand. Both studies share the theoretical background of non-verbal behavior and non-verbal clues of deceit by Ekman. The study by Porter and ten Brinke codes blink rate, micro expressions, and emotional expressions inconsistent with the intended emotional display in order to determine whether falsified emotional expressions can be reliably differentiated from genuine emotional expressions. To do so, a frame-by-frame analysis of recorded displays of emotional expression is conducted. Participants of the study are asked to view a timed slide show of emotional pictures from the International Affective

Picture System (IAPS), a standardized database of emotionally arousing pictures. These pictures are organized into five sets. Each set is defined by the expressions participants are instructed to show: four emotional sets, including three images each (1 neutral, 1 happy, 1 sad image), and one neutral set, including five images (1 neutral, 1 disgusting, 1 sad, 1 happy, 1 fearful). For the emotional sets participants are asked to express disgust, happiness, sadness, and fear. For the neutral set they are asked to retain a neutral facial expression. This way, Porter and ten Brinke want to test whether certain facial expressions cannot be inhibited and happen involuntarily, as Ekman and Darwin suggest. (cf. Darwin, 1948, p. 28; cf. Ekman, 2001, p. 123f.; cf. Porter and Ten Brinke, 2008, p. 509)

One major finding by Porter and ten Brinke is that falsifying an expression leads to higher blink rates whereas retaining a neutral expression reduces the blink rate. Moreover, during deception participants show at least one emotional expression, that was inconsistent. This can be an indication for an involuntary, possibly innate, aspect of deceptive human behavior, as suggested by Darwin and the psychophysiological approach in emotion theory. (cf. Darwin, 1948, p. 28; cf. Birbaumer, 1983, p. 50f.; cf. Porter and Ten Brinke, 2008, p. 512) But inconsistencies in falsified emotions vary in duration and frequency, depending on the instruction, they receive in the experiment. Thus, participants perform better in creating convincing falsified displays of happiness rather than convincing falsified displays of negative expressions. (cf. Porter and Ten Brinke, 2008, p. 512)

### **3. Methodology**

Many studies have investigated the presence of non-verbal behavior, such as eye movements and facial expression on people's faces in the moment they were telling a lie. But not a single study (to the best of my knowledge) has investigated the occurrence of a combination of non-verbal features occurring at the same time interval when telling a lie. Furthermore, no study can be found investigating the presence of facial expressions (and possible combinations) right after a lie has been told – once the liar believes to successfully have fooled the receiver of the lie or not.

For this reason, the study at hand aims to analyze and identify possible patterns in facial expressions and their combinations during and immediately after lying. To do so, new data will be collected through a quantitative exploratory experiment, in which participants' reactions to visual stimuli as well as their expressions when and after lying are recorded. In addition, the study aims to examine whether the type of lie (gray or real lie) has an influence on the ability to successfully tell and recognize a lie through facial expressions. By doing so, it tackles another, yet to be further investigated, issue of lie detection. Since the study conducts inductive primary research, it follows an explorative-descriptive research approach.

#### **3.1 Data Collection**

As mentioned above, new data will be collected. To do so, both unstructured (narrative) and structured interviews (with questionnaire) will be conducted. The narrative interviews will be recorded, as they concern the lying behavior of the participants. By conducting unstructured narrative interviews, participants can structure their narratives themselves and decide which information to in- or exclude in their narrative. (cf. Döring, 2023, p. 355) The structured interviews on the other hand, merely capture the judgement of the lie by an observing participant. Hence, the observing participant is judging the lying participant without being recorded. However, the observing participant simultaneously fills out a questionnaire, with their answers. This way, the evaluation metrics for lie detection are consistent and can be compared between each individual lie recording. (cf. Döring, 2023, p. 356)

With a percentage of 33.33 % undergraduate college students lie more often than other members from their local community who only lie with a percentage of 20.00 %. (cf. DePaulo

et al., 1996, pp. 981, 984) Therefore, the data for this study is collected from bachelor's degree students who are enrolled in Prof. Andrea Kohlhasse's course "User Centered Design and Development". This is an easily accessible, non-probabilistic sample, as is common in quantitative exploratory studies. (cf. Döring, 2023, p. 609) The experiment will be carried out in the usability laboratory (room A.1.61) at University of Applied Sciences Neu-Ulm. As most students are native German speakers, the study will be conducted in German. This way the participants will be able to talk more freely and unrestrained.

Research has shown that most lies are (at least partially) about the liars themselves. This goes hand in hand with the motives behind these lies: most lies are self-serving and intended to benefit the liar. In fact, self-serving lies are told twice as often as altruistic lies. Furthermore, self-serving lies are mostly told due to psychological reasons – to save face and protect oneself from embarrassment or conflict – rather than for material gain or personal convenience. (cf. DePaulo et al., 1996, p. 991) Due to this, the narrator will be put in a scenario, where he or she is instructed to formulate self-serving lies in order to avoid conflict or embarrassment towards the observer. Because lies are more likely to be told via more distant modalities as the telephone and less likely to be told in a face-to-face interaction, narrator and observer will be communicating through a video conference via Zoom. This way, the communication takes place in a distant as well as a face-to-face environment, potentially increasing the stakes of lying, making lying more visible. (cf. Ekman et al., 1991, p. 134; cf. DePaulo et al., 1996, p. 985)

### **3.2 Experimental Setup**

The participants are divided into two groups – observer and narrator. The observer is seated in front of a computer screen in the anteroom of the usability laboratory (see Figure 3). The narrator on the other hand is seated in front of a computer screen inside the laboratory (see Figure 4).



Figure 3: Position and view of the observer (outside the laboratory (anteroom))



Figure 4: Position and view of the narrator (inside the laboratory)

As the door is shut, the observer and the narrator cannot physically see or hear each other. The researcher remains in the same room as the narrator and monitors the experiment. Once the experiment has started, at some point narrator and observer are connected via Zoom and then are able to virtually see, hear and talk to each other. This process is later discussed in more detail. Each participant will take on each role once. Hence, there will be two alternating picture datasets and paper surveys, with six different scenarios each.

### 3.2.1 The narrator

After adjusting the distance to the eye tracker (approximately 60 cm), the narrator is presented with a slide show. As visual stimuli have proven to be more effective in triggering emotions (cf. Kasten, 1983, p. 103), the participants are asked to view multiple pictures from the Emotional Picture Set (EmoPicS), that trigger specific emotions to occur. The EmoPicS set is used, because other than self-photographed pictures, the affectivity of the pictures within this dataset have been validated within a study of Michèle Wessa et. al.. EmoPicS is a dataset containing 378 standardized and validated emotion-triggering color photographs. The photographs vary in arousal and valence<sup>3</sup>, and depict different semantic content (diverse animals, plants, and social situations). Images depicting social situations are of great interest as they are more likely to trigger emotions in the viewer. They may relate to the situation and thus become emotionally involved respective aroused. Consequently, according to Ekman, lying becomes more visible. (cf. Ekman, 2001, p. 31f.) The measured values of emotional

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<sup>3</sup> Arousal and valence are psychological measures for emotion. **Arousal** ranges from low (calm) to high (excited) and describes the felt intensity of an event. **Valence** on the other hand measures the felt pleasantness of an event and ranges from low (negative) to high (positive). (cf. Bestelmeyer, Kotz and Belin, 2017, p. 1351)

arousal and valence ranged from 1-9, with 1=sad and 9=happy for valence and 1=excited and 9=calm for arousal. (cf. Wessa et al., 2010).

Inspired by the study of Porter and ten Brinke the narrator is asked to randomly view pictures from two different picture sets (happy, sad). (cf. Porter and Ten Brinke, 2008, p. 509f.) The pictures for each picture set are chosen based on their valence value – the six pictures with the lowest normed valence value (1.40, 1.57, 1.63, 1.67, 1.74, 1.77) are assigned to the sad picture set, and the six pictures with the highest normed valence value (7.79, 7.64, 7.57, 7.52, 7.49, 7.48) were assigned to the happy picture set.(cf. Wessa et al., 2010)

At the beginning of the experiment, the narrator is instructed to keep a poker face at all times to test whether facial expressions (reactions) to emotional stimuli can be consciously inhibited or if they occur unconsciously and autonomously. The narrator's task is to fool the observer and convince him or her, that each statement consists of the truth. The intent is to raise the stakes of lying by telling the narratives virtually face to face. According to Ekman et al. once the stakes of the lie are high, it is more difficult to conceal the truly felt emotion and lies become more visible. (cf. Ekman et al., 1991, p. 134)

The slide show consists of six different scenarios (see Appendix 1a and Appendix 1b), instructing the narrator to either tell the truth, a lie, or a gray lie about the shown picture to the observer in the anteroom. The narrator will see a total of six pictures – three positive and three negative pictures. So, in the end, the narrator will have to tell a lie, a gray lie, and the truth for both a negative and a positive picture. The observer on the other hand is provided with a paper survey (see Appendix 2a and Appendix 2b), containing the corresponding scenario information to the one presented to the narrator. The scenarios serve to place the narrator and the observer in an imaginary situation to increase the emotional engagement with what is seen or heard. Because in addition to the representation of pictures, the imagination of concrete scenes is also part of the methods of emotion research. (cf. Kasten, 1983, p. 103)

The narrator navigates through the slide show independently by clicking the "Next"-button. Once skipped, the narrator cannot return to the previous slide. Each scenario consists of three slides:

- (1) Written scenario information (setting).
- (2) Picture with instructions on whether to tell a lie, gray lie, or the truth.
- (3) Instruction to switch the screen to Zoom, tell the narrative, and wait for the observer's judgement.

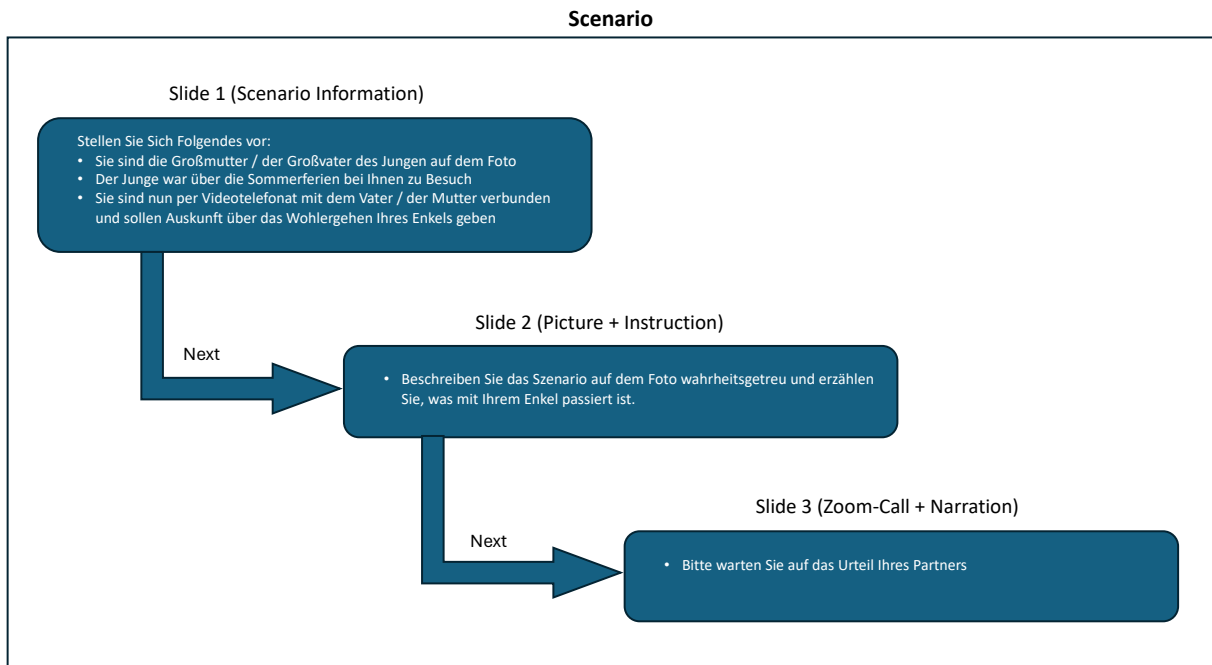


Figure 5: Slide show process (narrator perspective)

**Slide (1)** contains the scenario information for the narrator. The scenario shown in Figure 5 is scenario 1 from dataset 1 of the experiment. The narrator is asked to imagine the following:

- You are the grandmother / grandfather of the boy in the picture.
- The boy was visiting you over the summer vacation.
- You are now connected to the father / mother via video call and are expected to provide information about your grandchild's well-being.

Once the narrator has read and internalized the scenario setting, they will click on the “Next”-button. **Slide (2)** will then show the corresponding picture to the narrator. Right below the picture, the second slide will instruct the narrator on how to frame his story. In this case (Figure 5), the narrator is instructed to tell the truth about the happenings in the picture. Once the narrator knows what they would like to say to the observer and how, they will click on the “Next”-button. On **slide (3)** the narrator will read the instruction “Please wait for the judgement of your partner”. This will be the sign for the narrator to switch screen to the Zoom

Call, where they will be able to see and hear the observer. The narrator can switch screens through pressing the corresponding button (4 – Zoom) on the vision mixer (see Figure 6).

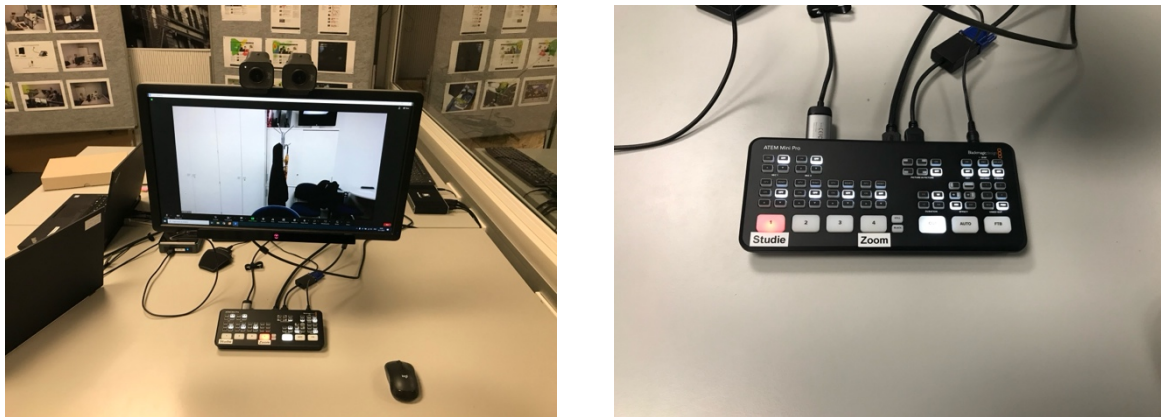


*Figure 6: Narrator's toolkit to navigate through study: mouse and vision board (left) + closeup of vision board (right)*

Once the narrator has switched to the Zoom Call screen, they will immediately start telling their story. The camera and microphone will be activated by the researcher, seated to the left of the narrator (see Figure 9). Once the narrator has finished their story, the observer will communicate, whether they believe the story to be a lie or the truth. Immediately after the observer expresses his or her judgment, the researcher turns off the narrator's camera and microphone. The narrator then switches screen back to the study by pressing the corresponding button (1 – Studie) on the vision mixer. Now, the narrator continues to the next scenario by clicking the "Next"-button. This process will be repeated for a total of six scenarios. Afterwards, the roles will be switched.

### 3.2.2 The observer

As mentioned earlier, the observer is seated in the anteroom of the laboratory. Other than the narrator, the observer will not be seeing any pictures. Instead, the observer is provided with a paper questionnaire containing the corresponding scenario information to the scenario of the narrator. Underneath the scenario information, there are three standardized questions for the observer to answer once the narrator has finished telling their story. For each question, multiple choice answers are available to the observer. Figure 7 shows the corresponding scenario information to Figure 5 as well as the three standardized questions that remain the same for all six scenarios.

#### Szenario 1:

Stellen Sie sich Folgendes vor:

- ☐ Sie sind Mutter/Vater und Ihr Kind befindet sich bei den Großeltern im Urlaub.
- ☐ Sie telefonieren nun mit den Großeltern im Ausland und erkundigen sich nach Ihrem Kind

**Wie schätzen Sie die Aussage Ihres Partners ein?**

Falsch  
☐

Eher falsch  
☐

Eher wahr  
☐

wahr  
☐

**Wie sicher sind Sie sich mit Ihrer Einschätzung?**

Unsicher  
☐

Eher unsicher  
☐

Eher sicher  
☐

sicher  
☐

**Auf Grundlage welcher Beobachtung kommen Sie zu Ihrer Einschätzung?  
(Mehrfachauswahl möglich)**

☐ Mimik

☐ Tonlage / Stimme

☐ andere

☐ Gestik

☐ Körpersprache

Figure 7: Extract Paper questionnaire Observer (Scenario information and standardized questions)

The observer remains dialed into the Zoom call throughout the whole experiment. But only when the narrator reaches slide 3 of a scenario can the observer see and hear the narrator. The only task for the observer is to wait until the narrator appears on the screen, listen to the narrative, and communicate their judgement of the story to the narrator. The observer is instructed to merely say, whether they believe the story to be a lie or the truth. No further information needs to be communicated. Once the observer communicated their judgement, the researcher will turn off the microphone and the camera of the narrator. The narrator will

then continue with the next scenario. As the narrator works on the next scenario, the observer is asked to answer the following three questions about the previous scenario:

(1) How do you assess your partner's narrative?

|       |              |             |      |
|-------|--------------|-------------|------|
| Wrong | Rather wrong | Rather true | True |
| O     | O            | O           | O    |

(2) How confident are you in your assessment?

|        |               |             |      |
|--------|---------------|-------------|------|
| Unsure | Rather unsure | Rather sure | Sure |
| O      | O             | O           | O    |

(3) Based on which observations did you come to your assessment? (multiple selection possible)

|                                             |                                        |                                 |
|---------------------------------------------|----------------------------------------|---------------------------------|
| <input type="checkbox"/> Facial Expressions | <input type="checkbox"/> Pitch / Voice | <input type="checkbox"/> others |
| <input type="checkbox"/> Gestures           | <input type="checkbox"/> Body language |                                 |

The answer options for question (1) and (2) are measured on an even numbered (psychometric Single-Item-Measure<sup>4</sup>) Likert scale. In this way, participants must position themselves, as no neutral value can be chosen. Solely, question (3) allows multiple selection and additional writing next to the "others"-field.

### 3.3 Apparatus and Setup

The experiment will consist of an eye tracking test as well as an emotion analysis of the recorded videos. The emotion analysis is conducted with the iMotions software (iMotions 10.0) utilizing the AFFDEX 2.0 toolkit. AFFDEX 2.0 uses facial AUs<sup>5</sup> to identify the seven basic emotions (anger, disgust, fear, joy, surprise, sadness and contempt), sentimentality and confusion, blinks and blink rate, attention, and expressiveness. (cf. Bishay et al., 2022, p. 5f.) Since the AFFDEX 2.0 toolkit cannot record saccade, fixation or gaze of the eyes, additional eye tracking is necessary to achieve a fine-grained analysis of changes in facial expressions on the participants' faces. The eye tracker used is the Tobii Pro X3-120. To achieve a detailed frame-

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<sup>4</sup> On this type of scale, the scale items serve as reflective indicators for the measurement of a latent attribute, such as the individual assessment of a situation. (cf. Döring, 2023, p. 266ff.)

<sup>5</sup> AUs are defined by the Facial Action Coding System (FACS) by Paul Ekman and describe even slight changes of basic facial movements in local facial regions. In facial action unit detection, the occurrence of different AUs in a given image is determined. (cf. Elgriing, 1987, p. 894; cf. Shao et al., 2022, p. 1274)

by-frame analysis of the participants' faces while lying, they will be recorded in the narrator role throughout the whole interview. Therefore, a consent form for collection and processing of personal data is signed by both, the narrator, and the observer, beforehand. As both iMotions and Zoom require a separate webcam, two Logitech StreamCams are attached to the narrator's screen: one recording the narrator's facial expressions for iMotions, the other to transport the image to Zoom. For switching screens the Blackmagic Design Atem Mini Pro vision mixer is used. The complete setup of the narrator's screen is depicted in Figure 8 below:

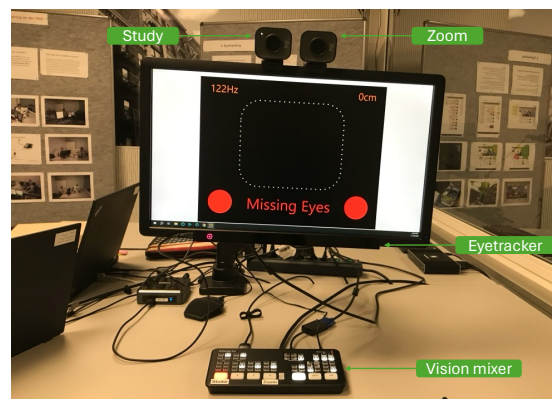


Figure 8: Setup Narrator Screen

The researcher, seated next to the narrator in the laboratory, utilizes two laptops: one for starting and monitoring the study, the other to turn the camera and the microphone of the narrator on and off once they switch to the Zoom call respective back to the study. This setup is shown in Figure 9.

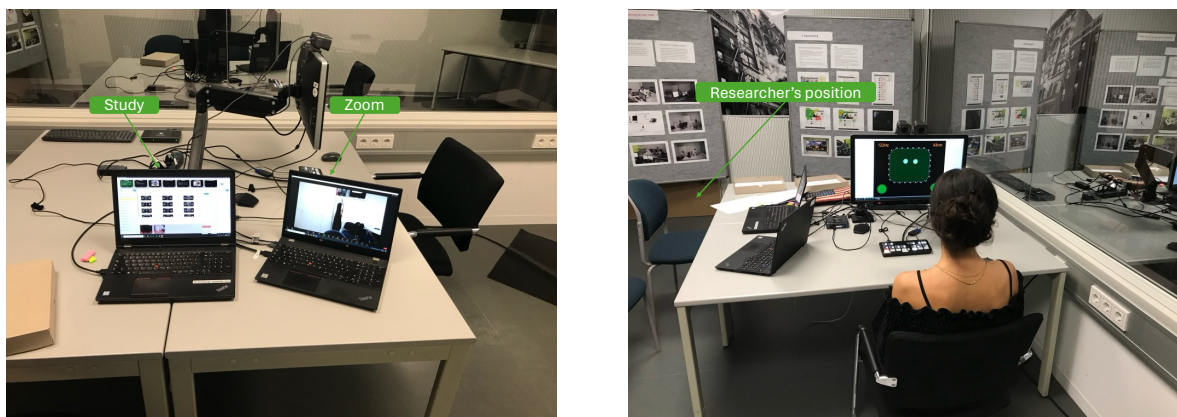


Figure 9: Setup Researcher's laptop (left) and Researcher's position (right)

As mentioned earlier, the observer is seated in front of a screen in the anteroom of the laboratory. The screen is also equipped with a Logitech C920 HD Pro webcam, which is turned on the entire time. Nevertheless, the observer will not see themselves. The observer will only

be able to see the narrator once the camera has been turned on by the researcher. Figure 10 shows the setup for the observer.



Figure 10: Setup Observer

### 3.4 Data Evaluation

The collected data will be evaluated using a k-Means cluster algorithm in PyCharm. The k-Means clustering algorithm is used to identify groups (clusters) and cluster centers of an unlabeled data set. As the collected data points will consist of multiple features, each data point behaves as a vector in a vector space. The k-Means algorithm calculates the Euclidean distance between each vector and identifies cluster centers (data points/vectors) which minimize the internal cluster variance. This means that the Euclidean distance between the cluster center and each data point is calculated iteratively until the internal cluster variance (the variance in Euclidean distance) from each data point within the cluster to the cluster center is minimalized. This way the dissimilarity of the datapoints assigned to the same cluster are smaller than the dissimilarities of data points assigned to another cluster. (cf. Hastie, Tibshirani and Friedman, 2009, p. 459f., 506f.)

The k-Means algorithm requires an initial number of clusters  $k$ . To determine and validate the number of clusters  $k$  the elbow criterion will be used. The elbow criterion is a graphic representation of the sum of squared errors (SSE) of the data set with increasing number of clusters. Ideally, there will be one number of clusters  $k$  where the decrease in SSE stagnates with increasing number of clusters  $k$ . At this point the graphed curve bends, forming an elbow-shape. The number of clusters  $k$  where the curve bends into the elbow is the ideal number of clusters  $k$  for the dataset. (cf. Syakur et al., 2018, p. 3) Once the number of clusters  $k$  has been identified the k-Means algorithm alternates the following two tasks: (1) sort each datapoint into the cluster with the cluster center closest to the datapoint, and (2) compute the mean vector for each datapoint and set the resulting vector as new cluster center. The algorithm

finishes once the data points do not change clusters anymore. This method requires an initial cluster center, which is typically chosen randomly from one observation in the dataset. (cf. Hastie, Tibshirani and Friedman, 2009, p. 460; cf. Müller and Guido, 2016, p. 170) To implement the k-Means algorithm the study at hand utilized the `sklearn.cluster.KMeans` toolkit in PyCharm. For final analysis of non-verbal cues for lying and lie detection the resulting cluster centers of the k-Means algorithm are analyzed and compared.

## 4. Results

### 4.1 Data Postprocessing

The collected raw data is postprocessed automatically by the iMotions software. For emotion analysis the software conducts a frame-by-frame analysis of the collected raw data. To do so, thresholds for emotion channel, action unit channel and valence need to be set. Since already mild expressions of emotion and AUs need to be detected the thresholds for the emotion as well as the action unit channel are set to 25 (as recommended by iMotions) and valence<sup>6</sup> to 10, to make the area for neutral time percentage small but distinct. (cf. IMOTIONS Help Center, 2022b, p. 3) In order to test the appearance of micro expressions the threshold for short expressions is set to  $\leq 0.25$  s and the threshold for long expressions is set to  $\geq 0.25$  s, as suggested by Ekman's definition. (cf. Ekman, 2001, p. 129)

After the postprocess the recorded videos are reviewed, and each scenario manually annotated. The annotations serve the purpose to distinctively separate the time period of lying (annotation name = Evaluation) and the time period when the narrator receives the observer's judgement (annotation name = Judgement). Once annotated, the AFFDEX and eye tracking data of both datasets is extracted. The exported CSV-files contain the time percentage<sup>7</sup>, count of total amount of expressions, count of short expressions ( $\leq 0.25$  s), and count of long expressions ( $\geq 0.25$  s) for emotions and AUs occurring for each stimulus for both datasets. Additionally, the blink rate (blinks per minute during annotation interval) and blink count are exported as well.<sup>8</sup> In iMotions different combinations of AU scores form an emotion. In Appendix 3 a breakdown of emotions by AUs is shown. (cf. IMOTIONS Help Center, 2024, p. 8) For analysis all count values for emotion and AUs are disregarded, because the annotation duration varies among participants, leading to a distorted representation of the effect of each AU and emotion on the lying performance. To make the performance of the narrators comparable only Time Percentage values are included in the cluster analysis.

The eye tracking data, as collected through a separate sensor, is exported in two separate CSV-files, one including fixation and the other including saccade data for each dataset.

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<sup>6</sup> A list of non-emotional measures (such as valence, engagement and attention) for AFFDEX data is added to the Appendix. (see Appendix 4)

<sup>7</sup> Time Percentage measures the amount of time an emotion (combination of AUs) is displayed out of a total time recorded for an annotation. (cf. IMOTIONS Help Center, 2022b, p. 5)

<sup>8</sup> This section only includes the parameters relevant and used for the cluster analysis. A list of the full exported parameters provided by each report is added to the Appendix (see Appendix 5,6,7).

As both AFFDEX and eye tracking data are divided into two datasets each, they each are brought together to be evaluated uniformly. The observer paper questionnaires are digitalized in Excel and linked to the corresponding entry in the AFFDEX dataset in PyCharm by using the parent stimulus and respondent name. In all datasets rows with missing values were eliminated through deletion. Only one participant's data is not taken into account because the instructions given were not carried out correctly and could not be replicated due to time constraints.

## **4.2 Demographics**

The participants (N=57) of the study are predominantly female (43 female, 14 male) and have a mean age of 22.83 (SD= 1.98) years. One additional participant not included in the previous noted statistics volunteered as observer when a participant's partner cancelled on short term.

## **4.3 Fixation and Saccade when Lying**

Fixation and saccade while lying are analyzed using the Fixation X- and Y- coordinates and the saccade direction values. For both indicators only data with excellent gaze calibration is regarded for further analysis. Figure 11 depicts the fixation points depending on the image (positive or negative) and the type of lie (gray or real) or truth that is told. The coordinates are measured relative to the top left corner of the screen the narrator is looking at.(cf. IMOTIONS Help Center, 2022a, p. 6f.)

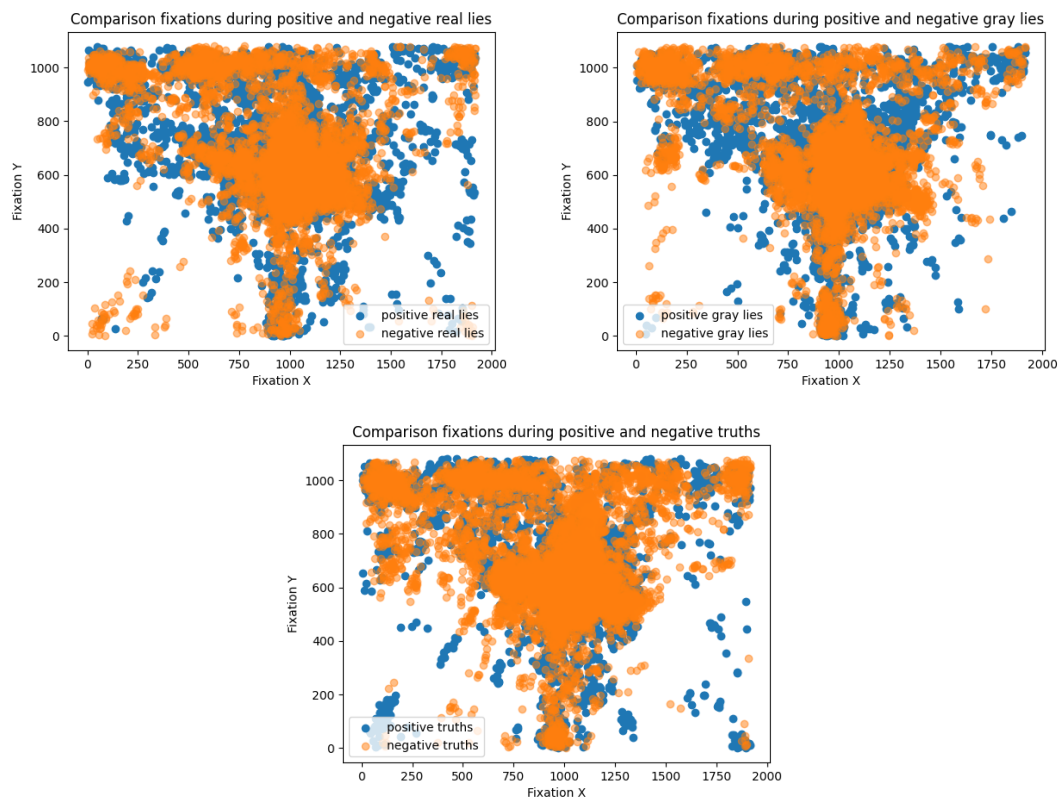


Figure 11: Fixation points while telling different kind of lies/truths

Meaning, if each figure within Figure 1 would be turned 90° to the right, the figures would be synchronic to the narrator's screen. Looking at all three graphics a similar V-shape is recognizable: So, participants more often fixate the middle and upper and lower right of the screen when telling a lie or the truth. On that right half of the screen fixation points are tendentially spreaded equally from top to bottom. When comparing the fixation points within one type of lie or truth (see Figure 12) only small differences in fixation points are visible, when telling the truth. So, the kind of image (stimuli) viewed by the participant does not influence the fixation points of the participant. Looking at gray and real lies, the fixation points for lies told based on a positive picture become slightly more scattered.

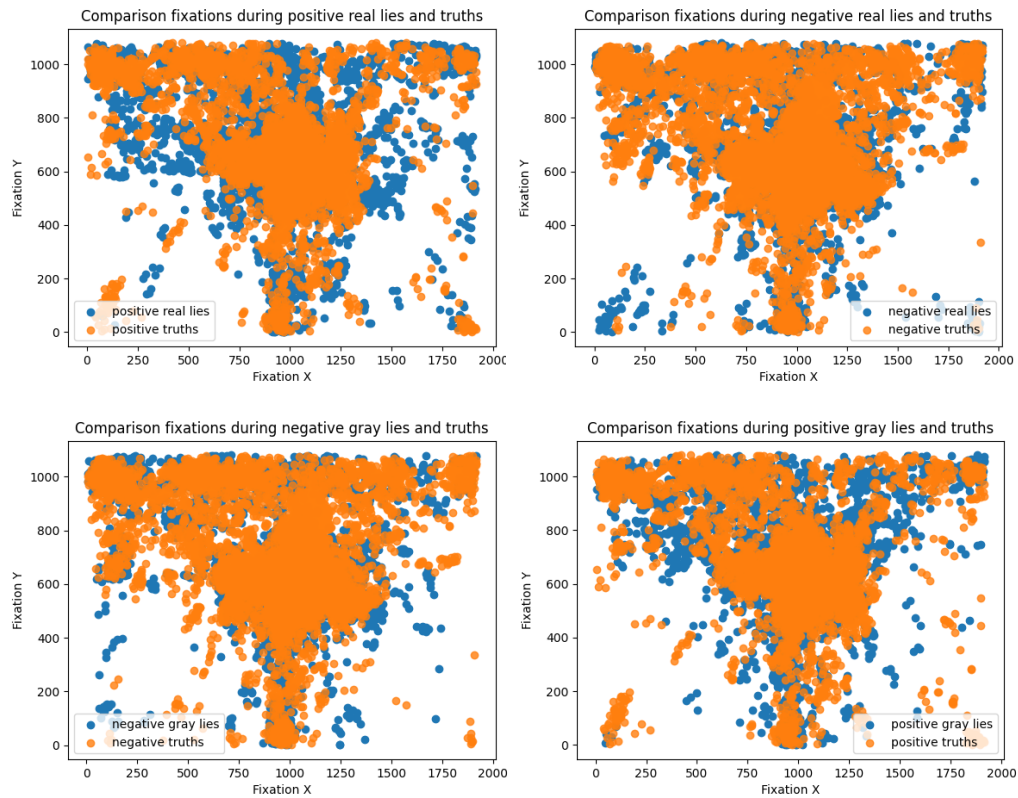


Figure 12: Comparison of fixation points between positive and negative lies and truths

For saccade direction evaluation, the values have been divided into four quadrants – (1) upper right, (2) lower right, (3) upper left, and (4) upper right. But due to missing data and almost equal distribution of data points amongst all four quadrants no distinct pattern can be recognized. Therefore, saccade direction analysis is inconclusive.

Due to only slight deviations in fixation points and no results in saccade direction, the eye tracking data is not included in the cluster analysis.

## 4.4 K-Means cluster analysis of emotions (AFFDEX data) during and after lying

Before conducting the k-Means cluster analysis, data has to be normalized. This is done by utilizing the `sklearn.preprocessing.Normalizer`. The Normalizer standardizes each data point so that the resulting vector has a Euclidean length of one. By doing so not the length but the direction of each vector becomes decisive for the analysis. (cf. Müller and Guido, 2016, p. 136)

### 4.4.1 Clusters and Cluster Centers for all lie evaluations

As mentioned earlier, the exported .csv-files contain the time percentage of AUs and aggregated emotions. So, in a first step the elbow criterion is used to identify whether patterns in lying emerge from aggregated emotion data or single AU data. In the following explanations, AU data is referred to as facial expressions and aggregated emotion data is referred to as emotions.

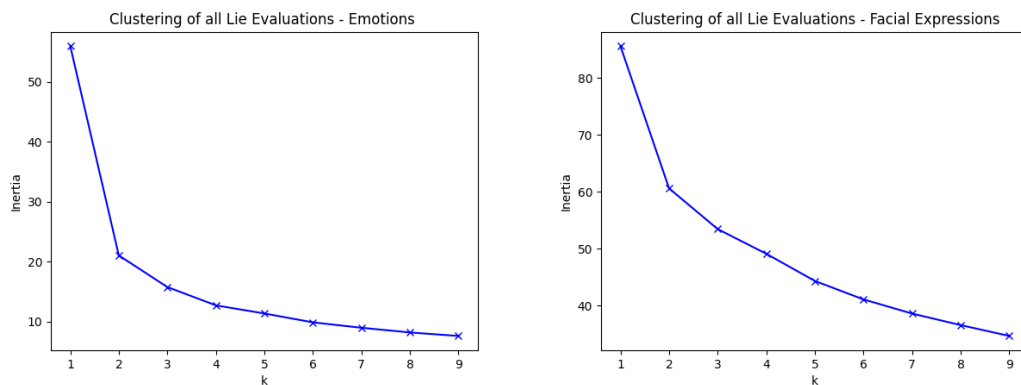


Figure 13: Comparison Elbow Criterion of all Lie Evaluation of Emotions and Facial Expressions

Figure 13 shows the elbow criterion of all lie evaluations (gray lie, real lie, and truth) for emotions and facial expressions. For emotions a clear bend in the curve is recognizable at  $k=3$ , indicating that the emotion data can be clustered in three distinct clusters. For facial expressions no clear bend and therefore no optimal number of clusters  $k$  can be identified. Due to that, the following cluster analysis is going to be conducted with the aggregated emotion data only.

Utilizing the `sklearn.cluster.KMeans` toolkit in PyCharm, the (AFFDEX) emotions data is clustered in  $k=3$  clusters. Figure 14 illustrates the distribution of each type of lie or truth within each cluster. The individual clusters are named after the type of lie or truth that can be found the most often.

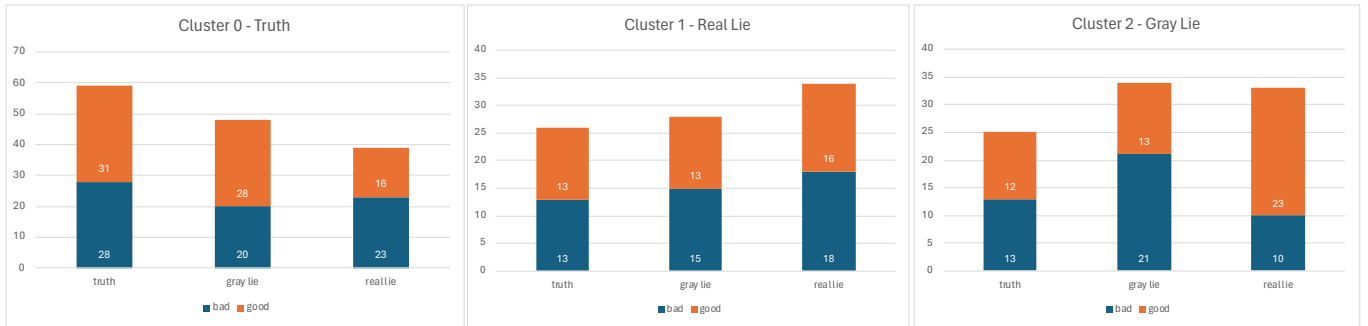


Figure 14: Within cluster distribution of each type of lie/truth.

**Cluster 0 – Truth** contains 59 truth, 48 gray lie, and 39 real lie narratives. When looking at the truth column itself, it can be seen, that both narratives about positive and negative pictures are represented almost equally. The other two columns are more imbalanced. For gray lies more positive indexed narratives are represented within in the cluster. Whereas for real lies negative indexed narratives are assigned to cluster 0. **Cluster 1 – Real Lie** is composed as follows: 34 real lie, 28 gray lie, and 26 truth narratives. The distribution of narratives influenced by positive and negative images are fairly balanced within each column. Finally, 34 gray lie, 33 real lie, and 25 truth narratives are assigned to **Cluster 2 – Gray Lie**. Striking here is that the distribution of positively and negatively indexed narratives within the columns for gray and real lies is opposite to one another. The truth column is almost evenly distributed. Overall, most datapoints are assigned to Cluster 0 – Truth, whereas Cluster 1 – Real Lie and Cluster 2 – Gray Lie contain an almost equal number of datapoints.

So, three clusters can be found, where each type of lie represents the majority within one cluster each. Especially the distinction between truth and lie (gray and real) can be seen clearly: either truthful narratives constitute a vast majority, or one type of lie, but there is always a distinct gap between the amount of truthful and deceptive narratives within one cluster. Nonetheless, comparing all three clusters, regarding the impact the type of picture shown has on clustering deceptive behavior, no pattern can be derived.

In Table 2 the cluster centers for each cluster are shown. Notable differences can be seen in the indicators Blink Rate, Joy Time Percentage, Engagement Time Percentage, Attention Time Percentage, Positive Time Percentage, and Neutral Time Percentage.

The blink rate is the lowest in the truth cluster ( $\approx 35.22$  blinks per minute,  $SD^9 \approx 19.89$ ) and the highest in the real lie cluster ( $\approx 41.57$  blinks per minute,  $SD \approx 18.82$ ). Clear differences

<sup>9</sup> Standard Deviation

between truth, real lie, and gray lie clusters, can be seen for the indicator Joy Time Percentage. With  $\approx 69.03\%$  ( $SD \approx 21.59$ ) Joy Time Percentage is the highest within the truth cluster, followed by the real lie cluster with  $\approx 20.45\%$  ( $SD \approx 12.37$ ). Lastly, joy time percentage is the lowest within the gray lie cluster ( $\approx 1.62\%$ ,  $SD \approx 3.72$ ). The decrease in Joy Time Percentage is accompanied by the increase in Neutral Time Percentage: The higher the Joy Time Percentage the lower the Neutral Time Percentage and vice versa. The same applies to Positive Time Percentage and Neutral Time Percentage: The higher the Positive Time Percentage the lower the Neutral Time Percentage and vice versa. For the truth cluster the Neutral Time Percentage lies at  $\approx 11.13\%$  ( $SD \approx 11.97$ ), for the real lie cluster at  $\approx 57.24\%$  ( $SD \approx 14.52$ ), and for the Gray Lie cluster at  $\approx 93.49\%$  ( $SD \approx 8.71$ ). The Positive Time Percentage also follows the same sequence from highest to lowest percentage, as the Joy Time Percentage: truth cluster ( $\approx 88.72\%$ ,  $SD \approx 12.20$ ), real lie cluster ( $\approx 39.96\%$ ,  $SD \approx 14.48$ ), gray lie cluster ( $\approx 4.75\%$ ,  $SD \approx 6.93$ ).

Attention Time Percentage is almost equal amongst each cluster, laying at  $\approx 100.00\%$ : truth cluster ( $\approx 99.85\%$ ,  $SD \approx 1.29$ ), real lie cluster ( $\approx 99.90\%$ ,  $SD \approx 0.77$ ), and gray lie cluster ( $100.00\%$ ,  $SD \approx 0.00$ ). Engagement Time Percentage on the other hand varies between the clusters. For the truth cluster Engagement Time Percentage lays at  $\approx 90.58\%$  ( $SD \approx 10.58$ ), for the real lie cluster at  $\approx 75.37\%$  ( $SD \approx 16.88$ ), and for the gray lie cluster at  $\approx 49.78\%$  ( $SD \approx 28.28$ ).

| Cluster 0 - Truth (count=146)     |                             |                    |                           |                    |
|-----------------------------------|-----------------------------|--------------------|---------------------------|--------------------|
| Indicator                         | Cluster Center Observations | Standard Deviation | Normalized Cluster Center | Standard Deviation |
| <b>Blink Rate</b>                 | <b>35.219589</b>            | <b>19.890607</b>   | <b>0.192305</b>           | <b>0.104802</b>    |
| Anger Time Percentage             | 0.004041                    | 0.035517           | 0.000024                  | 0.000209           |
| Sadness Time Percentage           | 0.030479                    | 0.313992           | 0.000201                  | 0.002102           |
| Disgust Time Percentage           | 0.294521                    | 1.788089           | 0.001698                  | 0.010432           |
| <b>Joy Time Percentage</b>        | <b>69.034384</b>            | <b>21.588132</b>   | <b>0.371961</b>           | <b>0.089661</b>    |
| Surprise Time Percentage          | 0.678699                    | 3.961415           | 0.003860                  | 0.023425           |
| Fear Time Percentage              | 0.407466                    | 2.914306           | 0.002345                  | 0.017380           |
| Contempt Time Percentage          | 0.380411                    | 1.453212           | 0.002271                  | 0.008661           |
| <b>Engagement Time Percentage</b> | <b>90.582534</b>            | <b>10.578587</b>   | <b>0.496667</b>           | <b>0.036406</b>    |
| <b>Attention Time Percentage</b>  | <b>99.848973</b>            | <b>1.291641</b>    | <b>0.552462</b>           | <b>0.051943</b>    |
| Sentimentality Time Percentage    | 3.094384                    | 4.544617           | 0.017039                  | 0.024276           |
| Confusion Time Percentage         | 0.069315                    | 0.742705           | 0.000364                  | 0.003820           |
| <b>Positive Time Percentage</b>   | <b>88.718836</b>            | <b>12.204563</b>   | <b>0.485813</b>           | <b>0.043666</b>    |
| Negative Time Percentage          | 0.154932                    | 0.752805           | 0.000943                  | 0.004606           |
| <b>Neutral Time Percentage</b>    | <b>11.126164</b>            | <b>11.971191</b>   | <b>0.066646</b>           | <b>0.074833</b>    |

| Cluster 1 - Real Lie (count=88)   |                             |                    |                           |                    |
|-----------------------------------|-----------------------------|--------------------|---------------------------|--------------------|
| Indicator                         | Cluster Center Observations | Standard Deviation | Normalized Cluster Center | Standard Deviation |
| <b>Blink Rate</b>                 | <b>41.566591</b>            | <b>18.820329</b>   | <b>0.263215</b>           | <b>0.114445</b>    |
| Anger Time Percentage             | 1.335455                    | 7.023324           | 0.007728                  | 0.039201           |
| Sadness Time Percentage           | 0.960341                    | 4.219802           | 0.005500                  | 0.023820           |
| Disgust Time Percentage           | 0.461364                    | 2.234044           | 0.002730                  | 0.012332           |
| <b>Joy Time Percentage</b>        | <b>20.446818</b>            | <b>12.365935</b>   | <b>0.131427</b>           | <b>0.079353</b>    |
| Surprise Time Percentage          | 6.664659                    | 17.312805          | 0.036931                  | 0.091049           |
| Fear Time Percentage              | 5.802500                    | 17.566812          | 0.031363                  | 0.091653           |
| Contempt Time Percentage          | 1.925227                    | 3.617792           | 0.012619                  | 0.024146           |
| <b>Engagement Time Percentage</b> | <b>75.367045</b>            | <b>16.883948</b>   | <b>0.476355</b>           | <b>0.080820</b>    |
| <b>Attention Time Percentage</b>  | <b>99.897045</b>            | <b>0.770492</b>    | <b>0.640902</b>           | <b>0.052795</b>    |
| Sentimentality Time Percentage    | 2.642955                    | 3.218982           | 0.016871                  | 0.020345           |
| Confusion Time Percentage         | 2.246136                    | 9.045602           | 0.012711                  | 0.050175           |
| <b>Positive Time Percentage</b>   | <b>39.955227</b>            | <b>14.483964</b>   | <b>0.258674</b>           | <b>0.098617</b>    |
| Negative Time Percentage          | 2.806477                    | 9.060429           | 0.016317                  | 0.049962           |
| <b>Neutral Time Percentage</b>    | <b>57.238636</b>            | <b>14.520341</b>   | <b>0.366626</b>           | <b>0.092485</b>    |

| Cluster 2 - Gray Lie (count=92)   |                             |                    |                           |                    |
|-----------------------------------|-----------------------------|--------------------|---------------------------|--------------------|
| Indicator                         | Cluster Center Observations | Standard Deviation | Normalized Cluster Center | Standard Deviation |
| <b>Blink Rate</b>                 | <b>35.471630</b>            | <b>19.746455</b>   | <b>0.226099</b>           | <b>0.115686</b>    |
| Anger Time Percentage             | 0.575326                    | 1.978710           | 0.003804                  | 0.013310           |
| Sadness Time Percentage           | 0.078587                    | 0.408462           | 0.000483                  | 0.002532           |
| Disgust Time Percentage           | 0.128370                    | 0.543635           | 0.000803                  | 0.003336           |
| <b>Joy Time Percentage</b>        | <b>1.614239</b>             | <b>3.719009</b>    | <b>0.010924</b>           | <b>0.025437</b>    |
| Surprise Time Percentage          | 0.784130                    | 2.042014           | 0.005071                  | 0.013330           |
| Fear Time Percentage              | 0.737826                    | 2.014091           | 0.004830                  | 0.013222           |
| Contempt Time Percentage          | 1.082065                    | 2.246335           | 0.007277                  | 0.015488           |
| <b>Engagement Time Percentage</b> | <b>49.781957</b>            | <b>28.283210</b>   | <b>0.313978</b>           | <b>0.166087</b>    |
| <b>Attention Time Percentage</b>  | <b>100.000000</b>           | <b>0.000000</b>    | <b>0.652656</b>           | <b>0.048598</b>    |
| Sentimentality Time Percentage    | 0.175870                    | 1.282111           | 0.001119                  | 0.003929           |
| Confusion Time Percentage         | 0.315326                    | 0.613839           | 0.001952                  | 0.007923           |
| <b>Positive Time Percentage</b>   | <b>4.754457</b>             | <b>6.926272</b>    | <b>0.031744</b>           | <b>0.047471</b>    |
| Negative Time Percentage          | 1.758478                    | 6.315246           | 0.012240                  | 0.046127           |
| <b>Neutral Time Percentage</b>    | <b>93.486522</b>            | <b>8.714711</b>    | <b>0.608670</b>           | <b>0.061743</b>    |

Table 2: Cluster Centers and Standard Deviation within each cluster.

#### 4.4.2 Clusters and Cluster Centers for the narrator's reaction when a real lie is believed

The second part of the cluster analysis addresses the behavior right after a lie is told and believed. By doing so the liar's behavior when he or she believes to successfully have fooled the observer is analyzed in the following subsection.

Before starting the cluster analysis for the reaction data (judgements) – once the narrator believes to have successfully fooled the observer with a real lie – the elbow criterion comes into play once again.

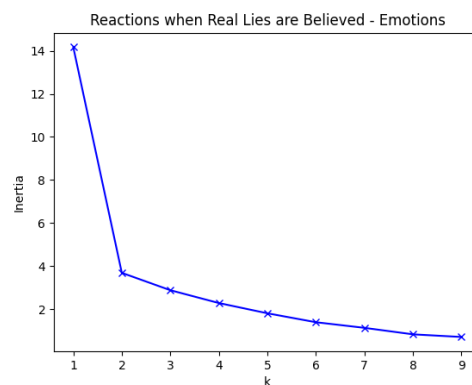


Figure 15: Elbow Criterion for reactions once a real lie is believed.

Looking at the curve depicted in Figure 15, the optimal number of clusters is  $k = 3$ . When clustering the data for reactions to believed real lies with the `sklearn.cluster.KMeans` toolkit, the resulting three clusters show the following distribution of good and bad stimuli (pictures) within each cluster (see Figure 16).

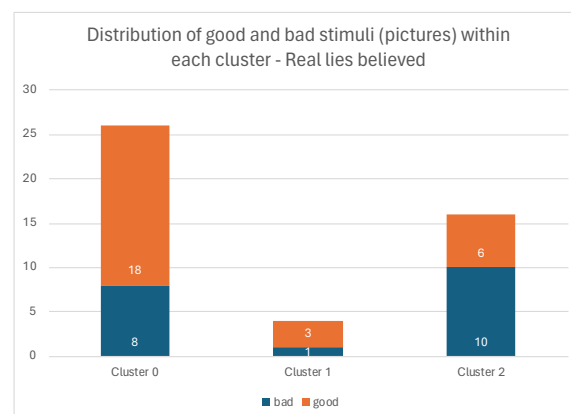


Figure 16: Within cluster distribution of positive and negative stimuli - real lies believed.

The most positive indexed judgements are assigned to Cluster 0 and the most negative indexed judgements are assigned to Cluster 2. Yet the difference in the amount of negative indexed judgements between Cluster 0 and Cluster 2 is only marginal.

Particularly noticeable is the distribution of observation counts within each cluster: Cluster 0 counts 26 observations, followed by Cluster 2 with 16 observations. Cluster 1 contains only 4 observations. The resulting cluster centers are shown in Table 3.

Distinctive indicators for differentiation between the clusters are Blink Rate, Joy Time Percentage, Engagement Time Percentage, Attention Time Percentage, Positive Time Percentage, and Neutral Time Percentage. Attention Time Percentage lays at 100.00% for all three clusters. But there is a significant difference visible in Joy Time Percentage: For Cluster 0 only 0.97% (SD  $\approx$  4.96) of the time joy is expressed, whereas in Cluster 1 the Joy Time Percentage lays at  $\approx$  94.45% (SD  $\approx$  11.11) and in Cluster 2 at  $\approx$  77.53% (SD  $\approx$  39.00). For Engagement Time Percentage, Positive Time Percentage, and Neutral Time Percentage Cluster 0 and Cluster 1 and 2 the values are opposite to each other. While Engagement Time Percentage is at  $\approx$  10.57% (SD  $\approx$  23.16) for Cluster 0, Engagement Time Percentage in Cluster 1 lays at  $\approx$  97.22% (SD  $\approx$  5.55) and in Cluster 2 lays at  $\approx$  86.17% (SD  $\approx$  25.25). The same can be derived for Positive Time Percentage and Neutral Time Percentage. For Cluster 0 Positive Time Percentage lays at  $\approx$  6.77% (SD  $\approx$  13.93) and Neutral Time Percentage at  $\approx$  91.56% (SD  $\approx$  15.88). For Cluster 1 Positive Time Percentage lays at  $\approx$  100.00% (SD  $\approx$  0.00) and Neutral Time Percentage at  $\approx$  0.00% (SD  $\approx$  0.00). For Cluster 2 Positive and Neutral Time Percentage are also high and lay at  $\approx$  96.46% (SD  $\approx$  9.76) and  $\approx$  3.54% (SD  $\approx$  9.76). Similar to the truth, real lie, and gray lie cluster (centers), the following finding can be transferred to the three clusters within this subsection: The higher the Positive and Joy Time Percentage the lower the Neutral Time Percentage and vice versa. But the higher Joy and Positive Time Percentage the lower the blink rate and vice versa.

| Cluster 0 - Reactions Real Lies Believed (count= 26) |                             |                    |                           |                    |
|------------------------------------------------------|-----------------------------|--------------------|---------------------------|--------------------|
| Indicator                                            | Cluster Center Observations | Standard Deviation | Normalized Cluster Center | Standard Deviation |
| <b>Blink Rate</b>                                    | <b>20.512692</b>            | <b>26.407830</b>   | <b>0.140460</b>           | <b>0.169539</b>    |
| Anger Time Percentage                                | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Sadness Time Percentage                              | 0.249615                    | 1.272794           | 0.001962                  | 0.010002           |
| Disgust Time Percentage                              | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| <b>Joy Time Percentage</b>                           | <b>0.971923</b>             | <b>4.955855</b>    | <b>0.006814</b>           | <b>0.034742</b>    |
| Surprise Time Percentage                             | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Fear Time Percentage                                 | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Contempt Time Percentage                             | 2.284615                    | 7.722233           | 0.014007                  | 0.044847           |
| <b>Engagement Time Percentage</b>                    | <b>10.572692</b>            | <b>23.164370</b>   | <b>0.070496</b>           | <b>0.144585</b>    |
| <b>Attention Time Percentage</b>                     | <b>100.000000</b>           | <b>0.000000</b>    | <b>0.699670</b>           | <b>0.046914</b>    |
| Sentimentality Time Percentage                       | 1.590769                    | 6.168211           | 0.011533                  | 0.043929           |
| Confusion Time Percentage                            | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| <b>Positive Time Percentage</b>                      | <b>6.772692</b>             | <b>13.933339</b>   | <b>0.050607</b>           | <b>0.105329</b>    |
| Negative Time Percentage                             | 1.666923                    | 5.921235           | 0.012455                  | 0.044072           |
| <b>Neutral Time Percentage</b>                       | <b>91.560385</b>            | <b>15.882886</b>   | <b>0.636608</b>           | <b>0.101783</b>    |

| Cluster 1 - Reactions Real Lies Believed (count= 4) |                             |                    |                           |                    |
|-----------------------------------------------------|-----------------------------|--------------------|---------------------------|--------------------|
| Indicator                                           | Cluster Center Observations | Standard Deviation | Normalized Cluster Center | Standard Deviation |
| <b>Blink Rate</b>                                   | <b>6.270000</b>             | <b>12.540000</b>   | <b>0.031188</b>           | <b>0.062377</b>    |
| Anger Time Percentage                               | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Sadness Time Percentage                             | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Disgust Time Percentage                             | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| <b>Joy Time Percentage</b>                          | <b>94.445000</b>            | <b>11.110000</b>   | <b>0.442130</b>           | <b>0.041367</b>    |
| Surprise Time Percentage                            | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Fear Time Percentage                                | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Contempt Time Percentage                            | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| <b>Engagement Time Percentage</b>                   | <b>97.222500</b>            | <b>5.555000</b>    | <b>0.455946</b>           | <b>0.020970</b>    |
| <b>Attention Time Percentage</b>                    | <b>100.000000</b>           | <b>0.000000</b>    | <b>0.469762</b>           | <b>0.026369</b>    |
| Sentimentality Time Percentage                      | 80.635000                   | 25.542394          | 0.374813                  | 0.104884           |
| Confusion Time Percentage                           | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| <b>Positive Time Percentage</b>                     | <b>100.000000</b>           | <b>0.000000</b>    | <b>0.469762</b>           | <b>0.026369</b>    |
| Negative Time Percentage                            | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| <b>Neutral Time Percentage</b>                      | <b>0.000000</b>             | <b>0.000000</b>    | <b>0.000000</b>           | <b>0.000000</b>    |

| Cluster 2 - Reactions Real Lies Believed (count= 16) |                             |                    |                           |                    |
|------------------------------------------------------|-----------------------------|--------------------|---------------------------|--------------------|
| Indicator                                            | Cluster Center Observations | Standard Deviation | Normalized Cluster Center | Standard Deviation |
| <b>Blink Rate</b>                                    | <b>18.856250</b>            | <b>24.077331</b>   | <b>0.099694</b>           | <b>0.125166</b>    |
| Anger Time Percentage                                | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Sadness Time Percentage                              | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Disgust Time Percentage                              | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| <b>Joy Time Percentage</b>                           | <b>77.528125</b>            | <b>38.998486</b>   | <b>0.390393</b>           | <b>0.185883</b>    |
| Surprise Time Percentage                             | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Fear Time Percentage                                 | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Contempt Time Percentage                             | 0.825625                    | 3.302500           | 0.005311                  | 0.021244           |
| <b>Engagement Time Percentage</b>                    | <b>86.172500</b>            | <b>25.251619</b>   | <b>0.448128</b>           | <b>0.091628</b>    |
| <b>Attention Time Percentage</b>                     | <b>100.000000</b>           | <b>0.000000</b>    | <b>0.543365</b>           | <b>0.087754</b>    |
| Sentimentality Time Percentage                       | 2.555625                    | 7.372687           | 0.012961                  | 0.037604           |
| Confusion Time Percentage                            | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| <b>Positive Time Percentage</b>                      | <b>96.455625</b>            | <b>9.762249</b>    | <b>0.518507</b>           | <b>0.062423</b>    |
| Negative Time Percentage                             | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| <b>Neutral Time Percentage</b>                       | <b>3.544375</b>             | <b>9.762249</b>    | <b>0.024857</b>           | <b>0.068141</b>    |

Table 3: Cluster Centers and Standard Deviation for the narrator's reaction when a real lie is believed.

#### 4.4.3 Clusters and Cluster Centers for the narrator's reaction when a gray lie is believed

After looking at the cluster distributions and cluster centers of the reactions when real lies are believed, this subsection focusses on cluster distribution and cluster centers of the reaction data once a gray lie is believed. To do so, at first the elbow criterion is determined (see Figure 17).

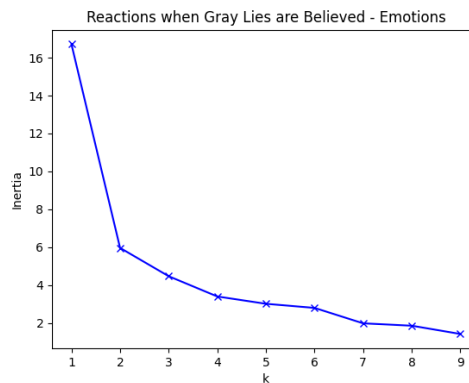


Figure 17: Elbow Criterion for reactions once a real lie is believed.

The curve for reactions to believed gray lies is not as smooth as the curve for reactions to believed real lies. Nevertheless, a distinct bend in the curve can be noticed at  $k = 3$ . Therefore, the number of clusters  $k$  for the k-Means algorithm is set to  $k = 3$ .

Once clustered with the `sklearn.cluster.KMeans` toolkit, the three resulting clusters unfold the cluster distribution as shown in Figure 18.



Figure 18: Within cluster distribution of positive and negative stimuli - gray lies believed.

Most negative indexed stimuli (pictures) are assigned to Cluster 1, whereas most positive indexed stimuli are assigned to Cluster 0. Nonetheless, the difference in positive indexed judgements within Cluster 0 and 1 is still marginal. Here too it is noticeable that the distribution of observation counts within each cluster vary greatly: Cluster 0 counts 20 observations,

followed by Cluster 1 with 28 observations. Cluster 2 on the other hand only counts 5 observations. In Table 4 the corresponding cluster centers are depicted.

Notable indicators for differentiation between the clusters are Blink Rate, Joy Time Percentage, Engagement Time Percentage, Attention Time Percentage, Positive Time Percentage, and Neutral Time Percentage. Attention Time Percentage is at 100.00% (SD= 0.00) for all three clusters. However, crucial differences can be found in Joy Time Percentage. With  $\approx 81.53\%$  (SD $\approx 27.81$ ) Cluster 0 has the highest Joy Time Percentage, followed by cluster 2 with a Joy Time Percentage of  $\approx 3.51\%$  (SD  $\approx 7.84$ ). In Cluster 1 there simply are no observations expressing joy – the Joy Time Percentage lays at 0.00% (SD= 0.00). Engagement Time Percentage is also the lowest in Cluster 1 ( $\approx 8.82\%$ , SD  $\approx 19.84$ ) and the highest in Cluster 0 ( $\approx 94.55\%$ , SD  $\approx 11.98$ ). For Cluster 2 Engagement Time Percentage lays at  $\approx 16.58\%$  (SD  $\approx 20.44$ ). Once again it can be observed that an increase in Positive Time Percentage leads to a decrease in Neutral Time Percentage and vice versa. Hence, for Cluster 0 Positive Time Percentage ( $\approx 93.16\%$ , SD  $\approx 22.65$ ) is the highest and Neutral Time Percentage ( $\approx 1.84\%$ , SD  $\approx 5.69$ ) the lowest among the three clusters. Second ranks Cluster 2 with a Positive Time Percentage of  $\approx 84.27\%$  (SD  $\approx 19.98$ ) and a Neutral Time Percentage of  $\approx 15.73\%$  (SD  $\approx 19.98$ ). Cluster 1 on the contrary has the lowest Positive Time Percentage ( $\approx 8.99\%$ , SD  $\approx 17.77$ ) and the highest Neutral Time Percentage ( $\approx 89.04\%$ , SD  $\approx 19.34$ ). The difference in Blink Rate is not quite as big as with the other indicators: it is the highest in Cluster 0 ( $\approx 29.60$  blinks per minute, SD  $\approx 34.60$ ) and the lowest in Cluster 2 ( $\approx 9.19$  blinks per minute, SD  $\approx 13.94$ ). For Cluster 1 the Blink Rate lays at  $\approx 17.88$  blinks per minute (SD  $\approx 21.33$ ).

| Cluster 0 - Reactions Gray Lies Believed (count= 20) |                             |                    |                           |                    |
|------------------------------------------------------|-----------------------------|--------------------|---------------------------|--------------------|
| Indicator                                            | Cluster Center Observations | Standard Deviation | Normalized Cluster Center | Standard Deviation |
| <b>Blink Rate</b>                                    | <b>29.600000</b>            | <b>34.600810</b>   | <b>0.138935</b>           | <b>0.150905</b>    |
| Anger Time Percentage                                | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Sadness Time Percentage                              | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Disgust Time Percentage                              | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| <b>Joy Time Percentage</b>                           | <b>81.533500</b>            | <b>27.808089</b>   | <b>0.404215</b>           | <b>0.121147</b>    |
| Surprise Time Percentage                             | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Fear Time Percentage                                 | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Contempt Time Percentage                             | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| <b>Engagement Time Percentage</b>                    | <b>94.448000</b>            | <b>11.976433</b>   | <b>0.477133</b>           | <b>0.045850</b>    |
| <b>Attention Time Percentage</b>                     | <b>100.000000</b>           | <b>0.000000</b>    | <b>0.510632</b>           | <b>0.057983</b>    |
| Sentimentality Time Percentage                       | 23.323000                   | 32.835142          | 0.111757                  | 0.152973           |
| Confusion Time Percentage                            | 0.500000                    | 2.236068           | 0.002882                  | 0.012888           |
| <b>Positive Time Percentage</b>                      | <b>93.164000</b>            | <b>22.650249</b>   | <b>0.470832</b>           | <b>0.120224</b>    |
| Negative Time Percentage                             | 5.000000                    | 22.360680          | 0.028820                  | 0.128885           |
| <b>Neutral Time Percentage</b>                       | <b>1.836000</b>             | <b>5.688592</b>    | <b>0.010981</b>           | <b>0.034115</b>    |

| Cluster 1 - Reactions Gray Lies Believed (count= 28) |                             |                    |                           |                    |
|------------------------------------------------------|-----------------------------|--------------------|---------------------------|--------------------|
| Indicator                                            | Cluster Center Observations | Standard Deviation | Normalized Cluster Center | Standard Deviation |
| <b>Blink Rate</b>                                    | <b>17.876786</b>            | <b>21.334338</b>   | <b>0.121405</b>           | <b>0.138816</b>    |
| Anger Time Percentage                                | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Sadness Time Percentage                              | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Disgust Time Percentage                              | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| <b>Joy Time Percentage</b>                           | <b>0.000000</b>             | <b>0.000000</b>    | <b>0.000000</b>           | <b>0.000000</b>    |
| Surprise Time Percentage                             | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Fear Time Percentage                                 | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Contempt Time Percentage                             | 7.770357                    | 20.941912          | 0.051112                  | 0.134933           |
| <b>Engagement Time Percentage</b>                    | <b>8.815714</b>             | <b>19.842357</b>   | <b>0.056858</b>           | <b>0.122141</b>    |
| <b>Attention Time Percentage</b>                     | <b>100.000000</b>           | <b>0.000000</b>    | <b>0.704152</b>           | <b>0.053141</b>    |
| Sentimentality Time Percentage                       | 0.147143                    | 0.778607           | 0.001193                  | 0.006314           |
| Confusion Time Percentage                            | 1.339286                    | 7.086834           | 0.009154                  | 0.048438           |
| <b>Positive Time Percentage</b>                      | <b>8.992857</b>             | <b>17.771747</b>   | <b>0.068794</b>           | <b>0.136326</b>    |
| Negative Time Percentage                             | 1.964286                    | 8.868723           | 0.013151                  | 0.057902           |
| <b>Neutral Time Percentage</b>                       | <b>89.042857</b>            | <b>19.337082</b>   | <b>0.622208</b>           | <b>0.123679</b>    |

| Cluster 2 - Reactions Gray Lies Believed (count= 5) |                             |                    |                           |                    |
|-----------------------------------------------------|-----------------------------|--------------------|---------------------------|--------------------|
| Indicator                                           | Cluster Center Observations | Standard Deviation | Normalized Cluster Center | Standard Deviation |
| <b>Blink Rate</b>                                   | <b>9.194000</b>             | <b>13.942951</b>   | <b>0.065408</b>           | <b>0.098772</b>    |
| Anger Time Percentage                               | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Sadness Time Percentage                             | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Disgust Time Percentage                             | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| <b>Joy Time Percentage</b>                          | <b>3.508000</b>             | <b>7.844126</b>    | <b>0.024801</b>           | <b>0.055456</b>    |
| Surprise Time Percentage                            | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Fear Time Percentage                                | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Contempt Time Percentage                            | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| <b>Engagement Time Percentage</b>                   | <b>16.576000</b>            | <b>20.438161</b>   | <b>0.117938</b>           | <b>0.144103</b>    |
| <b>Attention Time Percentage</b>                    | <b>100.000000</b>           | <b>0.000000</b>    | <b>0.730787</b>           | <b>0.047804</b>    |
| Sentimentality Time Percentage                      | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| Confusion Time Percentage                           | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| <b>Positive Time Percentage</b>                     | <b>84.274000</b>            | <b>19.981323</b>   | <b>0.609488</b>           | <b>0.120899</b>    |
| Negative Time Percentage                            | 0.000000                    | 0.000000           | 0.000000                  | 0.000000           |
| <b>Neutral Time Percentage</b>                      | <b>15.726000</b>            | <b>19.981323</b>   | <b>0.121299</b>           | <b>0.160308</b>    |

Table 4: Cluster Centers and Standard Deviation for the narrator's reaction when a gray lie is believed.

## 5. Discussion

During the analysis, eye tracking data proved to be rather inconclusive. For saccade no pattern in behavior could be derived, as each saccade direction is equally represented. So, saccade seems to be a very individual behavioral cue to deceit.

In fixation points only slight changes could be seen when looking at the kind of image shown to the participant. For gray and real lies, the fixation points are slightly more scattered when participants were shown a positive picture. This indicates that the participants tend to move their eyes more often to fixate new points on the screen, when they are asked to lie about a positive picture. The more frequent fixation of the middle, upper and lower right of the screen is rather due to the observer's position in front of the screen in the anteroom, than the narrator's lying behavior. Another reason could be the researcher's position to the left of the narrator, which is why participants might tend to avoid eye contact with the researcher and focus on the middle and right side of the screen.

But not all eye metrics are as inconclusive as fixation and saccade. The blink rate for instance does seem to constitute an indicator for deceitful behavior, at least when being looked at in combination with other emotion indicators: The cluster analysis of all evaluation annotations leads to the assumption that the blink rate tends to be higher when the participants are lying. This finding contradicts with Marchak who saw a decrease in blinks as relevant indicator for deceptive behavior. But the finding of this study aligns with Vrij et al. who saw an increase in blinks when people were lying in reverse order (cf. Vrij et al., 2008, p. 259) and especially Porter and ten Brinke who found that falsifying an expression leads to higher blink rates whereas neutralizing an expression reduces the blink rate (cf. Porter and Ten Brinke, 2008, p. 512).

The study at hand found that participants have a lower blink rate, express more positive and joyful emotions on their faces, when telling the truth. Neutral Time Percentage is the lowest out of all clusters, when telling the truth. This could be due to feeling safe and not having to worry about making and keeping up with a story. The Engagement Time Percentage is also the highest within the truth cluster, supporting the previous hypothesis.

In the real lie cluster participants have the highest blink rate, second highest joy, neutral, engagement and positive time percentage. Compared to the truth cluster, there is a noticeable decrease in the engagement indicator when telling a real lie. This could indicate that people do not feel the expression they are trying to depict. Meaning that the participants are falsifying

an emotion which leads to not only higher blink rates but also to a decrease in engagement of the expressed emotion.

Interestingly, the Positive Time Percentage is higher than the Negative Time Percentage, raising the question or assumption, that most lies are framed positive (regardless of the indexed picture shown). One reason for that could be Ekman's approach that the smile is the easiest expression to be falsified and therefore might be used by most liars to cover the true felt emotion. (cf. Ekman, 2001, p. 35) For iMotions the smile also increases the value for joy and positive time percentage, leading to a higher score for these indicators.

But this effect of higher scores in positive and joy time percentage compared to negative and sad time percentage is not limited to the real lie cluster. It can be observed in all clusters, supporting the hypothesis of the smile being the most used expression as it is the easiest to voluntarily make – either when telling the truth or when trying to falsify a not felt emotion.

Looking at the gray lie cluster, Engagement and Positive Time Percentage are the lowest and Neutral Time Percentage is the highest compared to all other clusters. This could be due to the fact, that the participants feel more comfortable to tell a gray instead of a real lie and therefore are less emotionally engaged when telling a gray lie. Taking Bryant's typology of lies into account, participants might not even consider the gray lie, a real lie but rather a white lie, (cf. Bryant, 2008, p. 35f.) and hence have no problem keeping a neutral face. This would also explain the high score in neutral time percentage of the gray lie cluster. It also comes into play that gray lies fall into the truth cluster more often than into the real lie cluster. Reason for that might be the Blink Rate of the gray lie cluster which is very close to the Blink Rate of the truth cluster. So, if participants are more positively emotional engaged while telling a real lie (while maintaining the same blink rate), they could easily be assigned to the truth cluster.

To summarize the findings to facial expressions during lying, the following points can be made. Engagement Time Percentage is lower for liars than for truth tellers. The decrease in emotional engagement could be due to three reasons: (1) an increase in cognitive load, forces the liar to focus on the consistency and credibility of the lie (cf. DePaulo et al., 2003, p. 102f.; cf. Vrij et al., 2008, pp. 254, 262; cf. Van Bockstaele et al., 2012, p. 1), which makes them forget about their facial expressiveness of the depicted emotion, and (2) the liars do not consider the lie to be a real lie, or (3) the lie is self-serving (e.g., gray lie) (cf. Bryant, 2008, p. 25f.), hence the liar could be less emotionally aroused and more able to keep a neutral face. Yet, as Vrij and Fisher stated, cognitive load can increase for a truth teller as well, for example if they are nervous

and want their story to be believed. (cf. Vrij and Fisher, 2020, p. 3) This could also be a reason, why truth narratives are also assigned to the real lie and gray lie clusters. Another reason for the assignment of truth narratives to any lie cluster could be, that the truth narratives, just as the lie narratives, are made up stories or descriptions as well. This could lead to similar behavior or facial expressions for truth and lie tellers.

A striking fact is, that the Blink Rate is higher, when participants are lying than when they are telling the truth. Also lies are mostly framed positive, as in all clusters the Positive Time Percentage is higher than the Negative time percentage. So, despite of seeing negative pictures as well, for all scenarios the participants smiled frequently when telling their story to the observer. This indicates that the participants did in fact voluntarily control their facial expressions (at least partially) during lying. This supports the statement made by Ekman and Friesen, that people control their facial expressions to follow display rules (personal and cultural) and in the need of the moment to protect oneself or someone else from harm and save face. (cf. Ekman and Friesen, 2003, p. 138f.) In this case, the smile could be a display rule learned in childhood, the participants used as habitual response to an unfamiliar situation.

It is also noteworthy, that the truth cluster contains compared to the other clusters, the highest numbers of data points. Whereas real lie and gray lie datapoints are represented to an almost equal number amongst all three clusters, the truth datapoints constitute the largest amount of the truth cluster. In no other cluster is the clear separation between one kind of lie and the truth as pronounced as in the truth cluster. This could indicate that participants show more similar expressions when they are telling the truth than when they are lying.

In General, the SD for the cluster centers is fairly high amongst all clusters. With an increase in data, the SD could be reduced, leading to more significant results. Looking at the assigned datapoints to each cluster, both truths are assigned to lie clusters and lies are assigned to truth clusters. Hence, no unambiguous assignment of narratives is possible. One reason for that could be the individual assessment of the narrator on how severe the lie is. These individual differences could also be a reason for the high SD.

The second part of the cluster analysis focusses on the reactions liars express on their faces once they believed to successfully have fooled the observer. Real lies and gray lies are viewed separately. First, gray lies appear to be believed more often (count= 53) than real lies (count= 46). This finding could also be due to the liar's individual assessment of the severity of the lie, and hence the difference between the truth and a gray lie would not be recognizable, if the

liar does not consider the gray lie to be a lie. Another reason could also be, that some participants are simply good liars and their facial expressions do not differ between the type of lies.

After conducting another cluster analysis based on the judgement data for real lies believed, three clusters emerge. Cluster 0 and 1 show a tendency that more narratives based on positive indexed pictures are assigned to these clusters, whereas negative indexed pictures slightly tend to be assigned to Cluster 2. Characteristic for Cluster 0 are the lowest Joy and Positive Time Percentages and the highest Neutral Time Percentages and Blink Rates among all three clusters. Cluster 1 and 2 show opposite scores in Time Percentages and Blink Rate as Cluster 0. Cluster 1 shows even more extreme values than Cluster 2. As Cluster 1 contains only 4 observations it appears to contain the outlier observations. But as it basically supports the same overall statement as Cluster 2 just with more extreme values, the reactions after telling a real lie can be divided in two groups with distinctive expression patterns: (1) participants keeping a poker face, and (2) participants showing duping delight. Cluster 1 and 2 clearly support the duping delight statement, as Joy, Engagement and Positive Time Percentage are very high. So, despite of being told to keep a poker face at all times, almost half of the participants in the believed real lies category, failed to do so. On the other hand, more than half of the participants within this category did succeed at keeping a poker face, as the high Neutral Time Percentage and the low Engagement Time Percentage of Cluster 0 suggests. But very interestingly, the participants in Cluster 0 could not suppress the expressions of contempt and sentimentality completely. This indicates that participants within Cluster 0 might feel some form of duping delight, but are better at concealing it, than participants in Cluster 1 and 2. This assumption is also supported by looking at the AUs for the emotional expressions of Sentimentality, Contempt and Joy. A smile increases the percentage for Joy, but it decreases the percentage in Contempt. A smirk on the other hand does increase Contempt Time Percentage. So, when the Joy Time Percentage is lower than the Contempt Time Percentage, smiles might have been suppressed to only be expressed in form of a smirk, or a lip suck which would explain the increase in Sentimentality Time Percentage for Cluster 0. It appears that participants telling real lies about positive indexed pictures, perform slightly better at keeping a neutral face than participants lying about a negative indexed picture.

Like believed real lies, believed gray lies go through a cluster algorithm as well and are subsequently clustered into three clusters. The resulting clusters show similar tendencies as the three clusters for real lies believed. Cluster 0 tends to contain more narratives based on positive indexed pictures. Observations in cluster 0 also have the highest Blink Rate, Joy, Engagement, and Positive Time Percentage and the lowest Neutral Time Percentage out of all clusters. Similar to the real lies believed clusters, Cluster 0 contains the most visible expressions of duping delight for gray lies believed.

For Cluster 1 on the contrary shows tendency that more narratives based on negative indexed pictures are assigned to it. The observations within cluster 1 have the highest Neutral Time Percentage as well as the lowest Positive and Engagement Time Percentage of all three clusters. But once again, despite having the highest Neutral time Percentage, it also has the highest percentage in Contempt Time. Based on the assumption, that a smirk functions as suppressed smile, this indicates, that participants within Cluster 0 might feel some form of duping delight but are better at concealing it and keeping a neutral face than participants within Cluster 1.

Cluster 2 appears to contain all observations that lay in between cluster 0 and 1 and only contains 5 observations. It does not depict as clear of a pattern as cluster 0 and 1 but also supports the appearance of duping delight expressions.

The gray lies believed clusters hence can be divided into two groups synchronously to the real lies believed clusters: (1) participants keeping a neutral poker face, and (2) participants expressing duping delight. The previous assumption, that participants telling, in this case, gray lies about positive indexed pictures, perform better at keeping a neutral face than participants lying about a negative indexed picture, solidifies after analysis of the reactions to believed gray lies.

In general, it can be derived that liars tend to show expressions of duping delight once they believe to have successfully fooled the observer – regardless of the kind of lie involved. But the extent to which degree they express their delight, separates liars in two groups. One group being able to suppress and conceal their delight achieving a higher Neutral Time Percentage and consequently keeping a neutral face. The other group is not successful at suppressing these expressions of felt emotion and reveals these on their faces. Still the SD for the cluster centers is fairly high for both real and gray lies believed. One reason for that could be the amount of data available but also individual differences in participants expressiveness. It is also

questionable whether the reactions to the lies believed are actually in the nature of the lying process or whether participants got into a game-like situation due to the experimental setup. Their expression of duping delight could then be caused because the participants are happy to have won the game. In a real lie situation perhaps, other emotions would emerge.

The cluster analysis of the participants reactions to believed lies shows that emotion and emotional expressions appear to have both a cognitive and an involuntary aspect to it. Participants seem to both either uncontrollably show or successfully inhibit their expressions of duping delight, when they believe to successfully have fooled the observer. These findings align with Izards developmental-psychological approach on emotion. Following his approach, the study at hand supports his arguments, that perception and cognition can influence emotion (in this case through suppression) and that inhibition of these can be learned. (cf. Izard, 2013, p. 5f.). This could be one reason, for the division of the participants into two groups. One group might have learned to inhibit the emotion and emotional expression of duping delight, whereas the other group has not.

While lying participants appear to mostly fall back on once learned display rules (e.g., smile even in negative contexts). This aligns with the cognitive-theoretical approach on emotion, stating that individual assessment of the situation leads to the arousal of emotion. This individual assessment is dependent on learned experience or social norms (display rules) of the individual. This could be one of the reasons, why participants mostly express positive and joyful expressions while lying.

## Conclusion

The thesis at hand analyzed the reliability of facial expressions as cues to deceit in the context of lie detection. The aim of the master thesis was to answer the questions how signs of lying and deceit manifest themselves in human non-verbal behavior and which cues can be observed on the liars faces when they are lying. Furthermore, it was examined whether the indications of deception are really limited to the period of the actual lie, or if liars also show signs of deception when they feel like they have gotten away with their lie. To do so data was collected through an experiment and a cluster analysis was carried out.

The fixation points and saccade direction were not meaningful indicators for deceitful behavior. Nonetheless, it would be valuable for further research to record the observer as well, to analyze where liars look on the observer's face. Consequently, eye tracking data was excluded from the cluster analysis. Hence, the cluster analyses were conducting using the emotion data.

The first conducted cluster analysis clustered the collected data in three clusters, where each truth, gray lie, and real lie narratives constituted the majority within each cluster.

The analysis of the resulting cluster centers of each cluster showed that liars tend to blink more often than truth tellers and are less emotionally engaged when telling a lie. Whereas both liars and truth tellers are more prone to showing positive expressions while talking, liars' positive expressions of emotion are measurably less genuine (decrease in Engagement Time Percentage) than those of a truth teller. As liars are less emotionally engaged when telling the truth, they perform better at keeping a neutral (poker) face. Striking for lying and truth telling is that regardless of the picture shown (positive or negative), all participants show more positive and joyful expressions than sad or fearful ones.

A second cluster analysis focused on the liars' reactions once they believed to have successfully fooled the observer. For each gray and real lies believed, the collected data was clustered into three distinct clusters. For both kind of lies two groups of reactions were identified: (1) Participants showing joy and positive expressions (duping delight), and (2) participants suppressing duping delight. Furthermore, it can be seen, that gray lies are believed slightly more often than real lies.

The findings on the liars' reactions to believed lies, contribute to a yet to be further examined field of lie detection. The expansion of the subject of investigation away from the period of the actual lie towards the liar's reaction to a believed lie, could reveal new insights on deceitful behavior, as shown by the study at hand. Future research could investigate the facial expressions of duping delight further, possibly reducing them to a few decisive facial muscle movements.

The cluster analysis of collected data also shows that emotion and emotional expressions have both a cognitive and an involuntary aspect to it. Following the developmental-psychological approach on emotion, the study found that perception and cognition can influence the expressed emotion. Furthermore, aligning with the cognitive-theoretical approach, cognition in this context appears to be the individual assessment of the situation, dependent on social norms and learned experience of the individual.

Because the overall standard deviations for all cluster centers throughout the study were relatively high, the results show a very simplified picture of reality. Further data collection could lead to a decrease in standard deviations, but deceitful behavior seems to be highly individual. Some people are good or even pathological liars, that account no moral values to lying whatsoever. But there are also people who are simply bad liars. If the data contains both good and bad liars, standard deviations are predestined to be high. Also, the study at hand did not work with real-time data, but data that was preprocessed by iMotions. A different configuration or different software might come to different results. Due to time limitations, the study at hand did not analyze all collected data, as they did not serve the purpose of answering the research question. Nevertheless, they are provided for further research.

Once more data is available it would be conceivable to develop and train an ANN and test the predictive power of the beforehand mentioned non-verbal indicators and conduct an automated cluster analysis.

As the context of the lie and how they are framed are also an important indicator for lie detection, further qualitative research on lying should be conducted. Perhaps the combination of non-verbal cues and the context of the lie uncover new insights on how lies can be detected.

To conclude, the study at hand contributes new insights on the liar's non-verbal behavior after telling a lie and aligns with already existing studies on non-verbal behavior during lying. Even

though some matching tendencies amongst all participants can be detected when lying, the high standard deviations show that lying and deceitful behavior are as individual as humans themselves. As the study at hand does only include scripted lies about emotionally arousing pictures, in reality not all humans do feel emotionally aroused in every lie situation, leading to deviating behavior when lying. Still, by showing emotional arousing pictures and achieving a distinctive cluster analysis, the study at hand confirms the relationship of emotion and lying. Also, it remains questionable, whether the experimental setup of the study truly puts the participants in a lie situation, or whether participants rather find themselves in a game-like situation, where emotions that deviate from lying may occur. Next to that, differing cultural and social norms and upbringings could influence the lying performance as well as the ability to recognize lies, hindering a reliable lie detection based on non-verbal human behavior.

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## Appendix

## Appendix 1a: Slide Show narrator – Dataset 1<sup>10</sup>

### Scenario 1

Bad (negative) indexed picture

Stellen Sie sich Folgendes vor:

- Sie sind die Großmutter / der Großvater des Jungen auf dem Foto
- Der Junge war über die Sommerferien bei Ihnen zu Besuch
- Sie sind nun per Videotelfonat mit dem Vater / der Mutter verbunden und sollen Auskunft über das Wohlergehen Ihres Enkels geben

### Scenario 1

Bad (negative) indexed picture

Beschreiben Sie das Szenario auf dem Foto wahrheitsgetreu und erzählen Sie was mit Ihrem Enkel passiert ist.

### Scenario 2

Good (positive) indexed picture

Stellen Sie sich Folgendes vor:

- Sie sind ein in Trennung lebender Elternteil und haben Ihr Kind für das Wochenende bei sich.
- Das Foto zeigt Sie mit Ihrem neuen Partner und dessen Kind am Wochenende.
- Ihr Ex-Partner ruft Sie nun per Videotelefonat an und erkundigt sich nach Ihrem Wochenende.

### Scenario 2

Good (positive) indexed picture

Beschreiben Sie das Foto, aber formulieren Sie die Geschichte so, dass:

- Ihr Ex-Partner nichts von der neuen Beziehung mitbekommt.

### Scenario 3

Good (positive) indexed picture

Stellen Sie sich Folgendes vor:

- Sie sind Vater und das erste Mal ohne die Mutter des Kindes alleine Zuhause
- Das Foto zeigt Sie mit Ihrem Kind
- Ihre Frau (die Mutter des Kindes) ruft Sie nun per Videotelefonat an und erkundigt sich nach Ihrem Tag.

### Scenario 3

Good (positive) indexed picture

Beschreiben Sie das Szenario auf dem Foto wahrheitsgetreu und erzählen Sie was Sie mit Ihrem Kind unternommen haben.

---

<sup>10</sup> The original pictures are for academic use only and may not be published or redistributed. Therefore, picture placeholders indicate the type of picture shown.

## Scenario 4

Bad (negative) indexed picture

Stellen Sie sich Folgendes vor:

- Sie sind die Tagesmutter / der Tagesvater des Kindes
- Die Mutter / der Vater ruft Sie per Videotelefonat an und erkundigt sich nach ihrem / seinem Kind.

## Scenario 4

Bad (negative) indexed picture

Übernehmen Sie die Informationen aus dem Bild und stellen Sie sie stattdessen in einen fröhlichen Kontext. Überzeugen Sie Ihren Partner davon, dass auf dem Bild ein fröhliches Szenario zu sehen ist und das Kind sehr glücklich ist.

## Scenario 5

Bad (negative) indexed picture

Stellen Sie sich Folgendes vor:

- Sie sind der Babysitter des Kindes auf dem Foto und haben es unbeaufsichtigt gelassen
- Während ihrer Unaufmerksamkeit hat sich das Kind die (abgebildeten) ernsthaften Verletzungen/Verbrennungen zugezogen
- Die Mutter / der Vater des Kindes befindet sich auf einer Geschäftsreise und erkundigt sich nun per Videotelefonat über das Wohlergehen ihres / seines Kindes

## Scenario 5

Bad (negative) indexed picture

Beschreiben Sie das Foto, aber formulieren Sie die Geschichte so, dass:

- Die Verletzungen weniger schlimm seien, als hier dargestellt
- Und, dass Sie als Babysitter nicht dafür verantwortlich sind, obwohl Sie es sind. Vermitteln Sie Ihrem Partner glaubwürdig, dass die Verletzungen nicht aufgrund Ihrer Unaufmerksamkeit entstanden sind.

## Scenario 6

Good (positive) indexed picture

Stellen Sie sich Folgendes vor:

- Sie sind Mutter / Vater des Kindes auf dem Foto
- Ihre Schwiegermutter ruft Sie an und erkundigt sich nach dem Wohlergehen des Kindes

## Scenario 6

Good (positive) indexed picture

Übernehmen Sie die Informationen aus dem Bild und stellen Sie sie stattdessen in einen Horror-Kontext. Überzeugen Sie Ihren Partner davon, dass auf dem Bild ein schreckliches Szenario zu sehen ist und das Kind fürchterliches erlebt.

## Appendix 1b: Slide Show narrator – Dataset 2<sup>11</sup>

### Scenario 1

Good (positive) indexed picture

Stellen Sie sich Folgendes vor:

- Sie sind Erzieher im Kindergarten
- Die Mutter / der Vater des Kindes hat Sie gebeten mit dem Kind nicht rauszugehen, da sie / er vermutet, dass es eine Erkältung hat
- Die Mutter / der Vater ruft Sie nun per Videotelefonat an und erkundigt sich nach dem Wohlergehen des Kindes

### Scenario 1

Good (positive) indexed picture

Beschreiben Sie das Foto, aber formulieren Sie die Geschichte so, dass:

- Der Vater / die Mutter des Kindes auf dem Foto nicht bemerkt, dass Sie mit dem Kind draußen waren

### Scenario 2

Bad (negative) indexed picture

Stellen Sie sich Folgendes vor:

- Sie sind Arzt / Ärztin und behandeln das Kind auf dem Foto
- Die Mutter / der Vater des Kindes befindet sich auf einer Geschäftsreise und hat mitbekommen, dass sich ihr / sein Kind im Krankenhaus befindet
- Die Mutter / der Vater erkundigt sich nun per Videotelefonat über das Wohlergehen ihres / seines Kindes

### Scenario 2

Bad (negative) indexed picture

Übernehmen Sie die Informationen aus dem Bild und stellen Sie sie stattdessen in einem fröhlichen Kontext dar. Überzeugen Sie Ihren

Partner davon, dass auf dem Bild ein fröhliches Szenario zu sehen ist und das Kind keine Verletzungen hat.

### Scenario 3

Bad (negative) indexed picture

Stellen Sie Sich Folgendes vor:

- Sie sind Regierungsbeauftragter des Landes in dem sich die gezeigte Szene abspielt
- Die Regierung hat sie beauftragt ausschließlich positive Nachrichten über ihr Land zu verbreiten
- Sie sind nun per Videotelfonat mit einem ausländischen Journalisten verbunden, der sich ein Bild über die Lage in der gezeigten Stadt machen möchte

### Scenario 3

Bad (negative) indexed picture

Beschreiben Sie das Foto, aber formulieren Sie die Geschichte so, dass:

- Der Journalist den Eindruck bekommt, dass auf diesem Bild niemand verwundet wurde

<sup>11</sup> The original pictures are for academic use only and may not be published. Therefore, picture placeholders indicate the type of picture shown.

## Scenario 4

Good (positive) indexed picture

Stellen Sie sich Folgendes vor:

- Sie sind die Mutter des Mädchens auf dem Foto.
- Das Foto zeigt Sie mit Ihrem Kind am Wochenende.
- Ihre Mutter / ihr Vater ruft Sie nun per Videotelefonat an und erkundigt sich nach Ihrem Wochenende.

## Scenario 4

Good (positive) indexed picture

Beschreiben Sie das Szenario auf dem Foto wahrheitsgetreu und erzählen Sie was Sie mit dem Kind am Wochenende unternommen haben.

## Scenario 5

Good (positive) indexed picture

Stellen Sie sich Folgendes vor:

- Sie sind Betreuer(in) in einem Ferienlager für Kinder.
- Das Foto zeigt zwei Geschwister im Ferienlager.
- Die Mutter / der Vater ruft Sie nun per Videotelefonat an und erkundigt sich nach ihren / seinen Kindern

## Scenario 5

Good (positive) indexed picture

Übernehmen Sie die Informationen aus dem Bild und stellen Sie sie stattdessen in einen Horror-Kontext. Überzeugen Sie Ihren Partner davon, dass auf dem Bild ein schreckliches Szenario zu sehen ist und die Kinder fürchterliches erleben.

## Scenario 6

Bad (negative) indexed picture

Stellen Sie sich Folgendes vor:

- Sie sind die Tante / der Onkel des Kindes auf dem Foto
- Das Kind war über das Wochenende bei Ihnen
- Während ihrer Unaufmerksamkeit hat sich das Kind die (abgebildeten) ernsthaften Verletzungen/Verbrennungen zugezogen
- Die Mutter / der Vater des Kindes erkundigt sich nun per Videotelefonat über das Wohlergehen ihres / seines Kindes

## Scenario 6

Bad (negative) indexed picture

Beschreiben Sie das Szenario auf dem Foto wahrheitsgetreu und erzählen Sie was mit dem Kind passiert ist.

## Appendix 2a: Paper questionnaire observer – Dataset 1

### Szenario 1:

Stellen Sie sich Folgendes vor:

- Sie sind Mutter/Vater und Ihr Kind befindet sich bei den Großeltern im Urlaub.
- Sie telefonieren nun mit den Großeltern im Ausland und erkundigen sich nach Ihrem Kind

**Wie schätzen Sie die Aussage Ihres Partners ein?**

Falsch

☐

Eher falsch

☐

Eher wahr

☐

wahr

☐

**Wie sicher sind Sie sich mit Ihrer Einschätzung?**

Unsicher

☐

Eher unsicher

☐

Eher sicher

☐

sicher

☐

**Auf Grundlage welcher Beobachtung kommen Sie zu Ihrer Einschätzung?  
(Mehrfachauswahl möglich)**

☐ Mimik

☐ Tonlage / Stimme

☐ andere

☐ Gestik

☐ Körpersprache

### Szenario 2:

Stellen Sie sich Folgendes vor:

- Sie sind ein in Trennung lebender Elternteil und haben Ihr Kind für das Wochenende zu Ihrer Ex-Frau / Ihrem Ex-Mann gebracht.
- Sie telefonieren nun mit Ihrem Ex-Partner und erkundigen sich nach dem Wochenende.

**Wie schätzen Sie die Aussage Ihres Partners ein?**

Falsch

☐

Eher falsch

☐

Eher wahr

☐

wahr

☐

**Wie sicher sind Sie sich mit Ihrer Einschätzung?**

Unsicher

☐

Eher unsicher

☐

Eher sicher

☐

sicher

☐

**Auf Grundlage welcher Beobachtung kommen Sie zu Ihrer Einschätzung?  
(Mehrfachauswahl möglich)**

☐ Mimik

☐ Tonlage / Stimme

☐ andere

☐ Gestik

☐ Körpersprache

### Szenario 3:

Stellen Sie sich Folgendes vor:

- Sie sind Mutter und sind das erste Mal ohne Ihr Baby zu Ihrer Familie gefahren.
- Ihr Mann passt in der Zeit allein auf Ihr Baby auf.
- Sie telefonieren nun mit Ihrem Mann und erkundigen sich nach dem gemeinsamen Tag.

**Wie schätzen Sie die Aussage Ihres Partners ein?**

Falsch  
O

Eher falsch  
O

Eher wahr  
O

wahr  
O

**Wie sicher sind Sie sich mit Ihrer Einschätzung?**

Unsicher  
O

Eher unsicher  
O

Eher sicher  
O

sicher  
O

**Auf Grundlage welcher Beobachtung kommen Sie zu Ihrer Einschätzung?  
(Mehrfachauswahl möglich)**

☐ Mimik

☐ Tonlage / Stimme

☐ andere

☐ Gestik

☐ Körpersprache

### Szenario 4:

Stellen Sie sich Folgendes vor:

- Sie sind Mutter/Vater und haben Ihr Kind bei der Tagesmutter / dem Tagesvater abgegeben.
- Sie telefonieren nun mit der Tagesmutter / dem Tagesvater und erkundigen sich nach Ihrem Kind.

**Wie schätzen Sie die Aussage Ihres Partners ein?**

Falsch  
O

Eher falsch  
O

Eher wahr  
O

wahr  
O

**Wie sicher sind Sie sich mit Ihrer Einschätzung?**

Unsicher  
O

Eher unsicher  
O

Eher sicher  
O

sicher  
O

**Auf Grundlage welcher Beobachtung kommen Sie zu Ihrer Einschätzung?  
(Mehrfachauswahl möglich)**

☐ Mimik

☐ Tonlage / Stimme

☐ andere

☐ Gestik

☐ Körpersprache

## Szenario 5:

Stellen Sie sich Folgendes vor:

- Sie sind Mutter/Vater und befinden sich gerade auf einer Dienstreise. Während Ihrer Abwesenheit haben Sie einen Babysitter beauftragt.
- Sie telefonieren nun mit dem Babysitter und erkundigen sich nach Ihrem Kind.

**Wie schätzen Sie die Aussage Ihres Partners ein?**

Falsch  
☐

Eher falsch  
☐

Eher wahr  
☐

wahr  
☐

**Wie sicher sind Sie sich mit Ihrer Einschätzung?**

Unsicher  
☐

Eher unsicher  
☐

Eher sicher  
☐

sicher  
☐

**Auf Grundlage welcher Beobachtung kommen Sie zu Ihrer Einschätzung?  
(Mehrfachauswahl möglich)**

☐ Mimik

☐ Tonlage / Stimme

☐ andere

☐ Gestik

☐ Körpersprache

## Szenario 6:

Stellen Sie sich Folgendes vor:

- Sie sind Großmutter / Großvater und wohnen mehrere hundert Kilometer von Ihrem Enkel entfernt.
- Sie telefonieren nun mit Ihrer / Ihrem Schwiegertochter / Schwiegersohn und erkundigen sich nach dem Wohlergehen Ihres Enkels.

**Wie schätzen Sie die Aussage Ihres Partners ein?**

Falsch  
☐

Eher falsch  
☐

Eher wahr  
☐

wahr  
☐

**Wie sicher sind Sie sich mit Ihrer Einschätzung?**

Unsicher  
☐

Eher unsicher  
☐

Eher sicher  
☐

sicher  
☐

**Auf Grundlage welcher Beobachtung kommen Sie zu Ihrer Einschätzung?  
(Mehrfachauswahl möglich)**

☐ Mimik

☐ Tonlage / Stimme

☐ andere

☐ Gestik

☐ Körpersprache

## Appendix 2b: Paper questionnaire observer – Data set 2

### Szenario 1

Stellen Sie sich Folgendes vor:

- Sie sind Vater / Mutter eines kleinen Kindes und haben es heute in den Kindergarten gebracht.
- Sie telefonieren nun mit der Betreuerin / dem Betreuer und erkundigen sich nach dem Wohlergehen Ihres Kindes.

**Wie schätzen Sie die Aussage Ihres Partners ein?**

Falsch  
☐

Eher falsch  
☐

Eher wahr  
☐

wahr  
☐

**Wie sicher sind Sie sich mit Ihrer Einschätzung?**

Unsicher  
☐

Eher unsicher  
☐

Eher sicher  
☐

sicher  
☐

**Auf Grundlage welcher Beobachtung kommen Sie zu Ihrer Einschätzung?  
(Mehrfachauswahl möglich)**

☐ Mimik

☐ Tonlage / Stimme

☐ andere

☐ Gestik

☐ Körpersprache

### Szenario 2:

Stellen Sie sich Folgendes vor:

- Sie sind Mutter/Vater und befinden sich gerade auf Geschäftsreise. Sie bekommen mit, dass sich Ihr Kind im Krankenhaus befindet.
- Sie telefonieren nun mit dem Krankenhaus und erkundigen sich nach Ihrem Kind.

**Wie schätzen Sie die Aussage Ihres Partners ein?**

Falsch  
☐

Eher falsch  
☐

Eher wahr  
☐

wahr  
☐

**Wie sicher sind Sie sich mit Ihrer Einschätzung?**

Unsicher  
☐

Eher unsicher  
☐

Eher sicher  
☐

sicher  
☐

**Auf Grundlage welcher Beobachtung kommen Sie zu Ihrer Einschätzung?  
(Mehrfachauswahl möglich)**

☐ Mimik

☐ Tonlage / Stimme

☐ andere

☐ Gestik

☐ Körpersprache

### Szenario 3:

Stellen Sie sich Folgendes vor:

- Sie sind Journalist und erkundigen sich nach der Atmosphäre eines touristischen Ausflugsziels
- Sie telefonieren nun mit einem Repräsentanten des Urlaubslandes.

**Wie schätzen Sie die Aussage Ihres Partners ein?**

Falsch  
○

Eher falsch  
○

Eher wahr  
○

wahr  
○

**Wie sicher sind Sie sich mit Ihrer Einschätzung?**

Unsicher  
○

Eher unsicher  
○

Eher sicher  
○

sicher  
○

**Auf Grundlage welcher Beobachtung kommen Sie zu Ihrer Einschätzung?  
(Mehrfachauswahl möglich)**

☐ Mimik

☐ Tonlage / Stimme

☐ andere

☐ Gestik

☐ Körpersprache

### Szenario 4:

Stellen Sie sich Folgendes vor:

- Sie sind Großmutter / Großvater und wohnen mehrere Kilometer von ihrer Enkelin entfernt
- Sie telefonieren nun mit Ihrer Tochter / Ihrem Sohn und erkundigen sich nach dem Wochenende der beiden.

**Wie schätzen Sie die Aussage Ihres Partners ein?**

Falsch  
○

Eher falsch  
○

Eher wahr  
○

wahr  
○

**Wie sicher sind Sie sich mit Ihrer Einschätzung?**

Unsicher  
○

Eher unsicher  
○

Eher sicher  
○

sicher  
○

**Auf Grundlage welcher Beobachtung kommen Sie zu Ihrer Einschätzung?  
(Mehrfachauswahl möglich)**

☐ Mimik

☐ Tonlage / Stimme

☐ andere

☐ Gestik

☐ Körpersprache

## Szenario 5:

Stellen Sie sich Folgendes vor:

- Sie sind Mutter / Vater von zwei Kindern und haben diese über den Sommer in ein Ferienlager gebracht
- Sie telefonieren nun mit dem Betreuer / der Betreuerin und erkundigen sich nach ihren Kindern.

**Wie schätzen Sie die Aussage Ihres Partners ein?**

Falsch

☐

Eher falsch

☐

Eher wahr

☐

wahr

☐

**Wie sicher sind Sie sich mit Ihrer Einschätzung?**

Unsicher

☐

Eher unsicher

☐

Eher sicher

☐

sicher

☐

**Auf Grundlage welcher Beobachtung kommen Sie zu Ihrer Einschätzung?  
(Mehrfachauswahl möglich)**

☐ Mimik

☐ Tonlage / Stimme

☐ andere

☐ Gestik

☐ Körpersprache

## Szenario 6:

Stellen Sie sich Folgendes vor:

- Sie sind Mutter/Vater und haben Ihr Kind über das Wochenende bei Ihrer Schwester / Ihrem Bruder gelassen.
- Sie telefonieren nun mit Ihrer Schwester / Ihrem Bruder und erkundigen sich nach Ihrem Kind.

**Wie schätzen Sie die Aussage Ihres Partners ein?**

Falsch

☐

Eher falsch

☐

Eher wahr

☐

wahr

☐

**Wie sicher sind Sie sich mit Ihrer Einschätzung?**

Unsicher

☐

Eher unsicher

☐

Eher sicher

☐

sicher

☐

**Auf Grundlage welcher Beobachtung kommen Sie zu Ihrer Einschätzung?  
(Mehrfachauswahl möglich)**

☐ Mimik

☐ Tonlage / Stimme

☐ andere

☐ Gestik

☐ Körpersprache

### Appendix 3: Breakdown of emotions/expressions by AUs

| Aggregated Emotion/Expression | AUs, contributing to aggregated emotion/expression                                                                          | AUs, counteracting to aggregated emotion/expression           |
|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|
| Joy                           | Smile<br>Cheek Raise                                                                                                        |                                                               |
| Anger                         | Mouth Open<br>Lip Press<br>Chin Raise<br>Upper Lip Raise<br>Lid Tighten<br>Eye Widen<br>Brow Furrow                         | Smile<br>Nose Wrinkle<br>Outer Brow Raise<br>Inner Brow Raise |
| Disgust                       | Mouth Open<br>Chin Raise<br>Upper Lip Raise<br>Nose Wrinkle                                                                 | Smile<br>Inner Brow Raise                                     |
| Surprise                      | Jaw Drop<br>Eye Widen<br>Outer Brow Raise<br>Inner Brow Raise                                                               |                                                               |
| Fear                          | Mouth Open<br>Lip Stretcher<br>Eye Widen<br>Brow Furrow<br>Outer Brow Raise<br>Inner Brow Raise                             | Smile<br>Nose Wrinkle                                         |
| Sadness                       | Chin Raise<br>Lip Corner Depressor<br>Cheek Raise<br>Brow Furrow<br>Inner Brow Raise                                        | Smile<br>Nose Wrinkle<br>Outer Brow Raise                     |
| Contempt                      | Smirk<br>Brow Furrow                                                                                                        | Smile<br>Outer Brow Raise                                     |
| Sentimentality                | Smile<br>Lip Suck<br>Lip Press<br>Chin Raise<br>Lip Corner Depressor<br>Cheek Raise<br>Brow Furrow<br>Inner Brow Raise      | Mouth Open<br>Outer Brow Raise                                |
| Confusion                     | Jaw Drop<br>Lip Pucker<br>Lip Corner Depressor<br>Dimpler<br>Nose Wrinkle<br>Lid Tighten<br>Brow Furrow<br>Inner Brow Raise | Smile                                                         |

(cf. IMOTIONS Help Center, 2024, p. 8)

| Aggregated Emotion/Expression | AUs, contributing to aggregated emotion/expression                                                                                                                       | AUs, counteracting to aggregated emotion/expression           |
|-------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|
| Engagement                    | Smile<br>Lip Suck<br>Mouth Open<br>Lip Press<br>Chin Raise<br>Lip Corner Depressor<br>Nose Wrinkle<br>Cheek Raise<br>Brow Furrow<br>Outer Brow Raise<br>Inner Brow Raise |                                                               |
| Positive                      | Cheek Raise<br>Smile                                                                                                                                                     |                                                               |
| Negative                      | Lip Press<br>Chin Raise<br>Lip Corner Depressor<br>Nose Wrinkle<br>Brow Furrow<br>Inner Brow Raise                                                                       | Smile<br>Nose Wrinkle<br>Outer Brow Raise<br>Inner Brow Raise |

(cf. IMOTIONS Help Center, 2024, p. 5)

## Appendix 4: Breakdown of non-emotion measures AFFDEX

| Expression | Description                                                                             | Interpretation                                                 |
|------------|-----------------------------------------------------------------------------------------|----------------------------------------------------------------|
| Attention  | Measure of Point of focus based on the narrator's head position                         | The higher the value the higher the focus.                     |
| Engagement | Measure of emotional responsiveness triggered by stimuli (whether positive or negative) | The higher the value the higher the emotional engagement.      |
| Valence    | Measure of positive or negative experience of the narrator                              | -10 negative effect<br>0 neutral effect<br>+10 positive effect |

(cf. IMOTIONS Help Center, 2024, p. 7)

## Appendix 5: List of Full Parameters of AFFDEX data

- Study Name
- Respondent Name
- Gender
- Age
- Group
- Type
- Label
- Start (ms)
- Duration (ms)
- Parent Stimulus
- Comment
- Blink Count
- Blink Rate
- Interblink Interval
- Count Frames
- Anger Threshold
- Anger Frames  $\geq$  Threshold
- Anger Time Percentage
- Anger Long expressions Count ( $\geq$  0.25 sec)
- Anger Short expressions Count ( $<$  0.25 sec)
- Sadness Threshold
- Sadness Frames  $\geq$  Threshold
- Sadness Time Percentage
- Sadness Long expressions Count ( $\geq$  0.25 sec)
- Sadness Short expressions Count ( $<$  0.25 sec)
- Disgust Threshold
- Disgust Frames  $\geq$  Threshold
- Disgust Time Percentage
- Disgust Long expressions Count ( $\geq$  0.25 sec)
- Disgust Short expressions Count ( $<$  0.25 sec)
- Joy Threshold
- Joy Frames  $\geq$  Threshold
- Joy Time Percentage
- Joy Long expressions Count ( $\geq$  0.25 sec)
- Joy Short expressions Count ( $<$  0.25 sec)
- Surprise Threshold
- Surprise Frames  $\geq$  Threshold
- Surprise Time Percentage
- Surprise Long expressions Count ( $\geq$  0.25 sec)
- Surprise Short expressions Count ( $<$  0.25 sec)
- Fear Threshold
- Fear Frames  $\geq$  Threshold
- Fear Time Percentage
- Fear Long expressions Count ( $\geq$  0.25 sec)
- Fear Short expressions Count ( $<$  0.25 sec)
- Contempt Threshold
- Contempt Frames  $\geq$  Threshold
- Contempt Time Percentage
- Contempt Long expressions Count ( $\geq$  0.25 sec)
- Contempt Short expressions Count ( $<$  0.25 sec)
- Engagement Threshold
- Engagement Frames  $\geq$  Threshold
- Engagement Time Percentage
- Engagement Long expressions Count ( $\geq$  0.25 sec)
- Engagement Short expressions Count ( $<$  0.25 sec)
- Attention Threshold
- Attention Frames  $\geq$  Threshold
- Attention Time Percentage
- Attention Long expressions Count ( $\geq$  0.25 sec)
- Attention Short expressions Count ( $<$  0.25 sec)
- Sentimentality Threshold
- Sentimentality Frames  $\geq$  Threshold
- Sentimentality Time Percentage
- Sentimentality Long expressions Count ( $\geq$  0.25 sec)
- Sentimentality Short expressions Count ( $<$  0.25 sec)
- Confusion Threshold
- Confusion Frames  $\geq$  Threshold
- Confusion Time Percentage
- Confusion Long expressions Count ( $\geq$  0.25 sec)
- Confusion Short expressions Count ( $<$  0.25 sec)
- Positive Threshold
- Positive Frames  $\geq$  Threshold
- Positive Time Percentage
- Positive Long expressions Count ( $\geq$  0.25 sec)
- Positive Short expressions Count ( $<$  0.25 sec)
- Negative Threshold
- Negative Frames  $\leq$  Threshold
- Negative Time Percentage
- Negative Long expressions Count ( $\geq$  0.25 sec)
- Negative Short expressions Count ( $<$  0.25 sec)

- Neutral Threshold
- Neutral Frames Between Threshold
- Neutral Time Percentage
- Neutral Long expressions Count ( $\geq 0.25$  sec)
- Neutral Short expressions Count ( $< 0.25$  sec)
- Brow Furrow Threshold
- Brow Furrow Frames  $\geq$  Threshold
- Brow Furrow Time Percentage
- Brow Furrow Long expressions Count ( $\geq 0.25$  sec)
- Brow Furrow Short expressions Count ( $< 0.25$  sec)
- Brow Raise Threshold
- Brow Raise Frames  $\geq$  Threshold
- Brow Raise Time Percentage
- Brow Raise Long expressions Count ( $\geq 0.25$  sec)
- Brow Raise Short expressions Count ( $< 0.25$  sec)
- Lip Corner Depressor Threshold
- Lip Corner Depressor Frames  $\geq$  Threshold
- Lip Corner Depressor Time Percentage
- Lip Corner Depressor Long expressions Count ( $\geq 0.25$  sec)
- Lip Corner Depressor Short expressions Count ( $< 0.25$  sec)
- Smile Threshold
- Smile Frames  $\geq$  Threshold
- Smile Time Percentage
- Smile Long expressions Count ( $\geq 0.25$  sec)
- Smile Short expressions Count ( $< 0.25$  sec)
- Inner Brow Raise Threshold
- Inner Brow Raise Frames  $\geq$  Threshold
- Inner Brow Raise Time Percentage
- Inner Brow Raise Long expressions Count ( $\geq 0.25$  sec)
- Inner Brow Raise Short expressions Count ( $< 0.25$  sec)
- Eye Closure Threshold
- Eye Closure Frames  $\geq$  Threshold
- Eye Closure Time Percentage
- Eye Closure Long expressions Count ( $\geq 0.25$  sec)
- Eye Closure Short expressions Count ( $< 0.25$  sec)
- Nose Wrinkle Threshold
- Nose Wrinkle Frames  $\geq$  Threshold
- Nose Wrinkle Time Percentage
- Nose Wrinkle Long expressions Count ( $\geq 0.25$  sec)
- Nose Wrinkle Short expressions Count ( $< 0.25$  sec)
- Upper Lip Raise Threshold
- Upper Lip Raise Frames  $\geq$  Threshold
- Upper Lip Raise Time Percentage
- Upper Lip Raise Long expressions Count ( $\geq 0.25$  sec)
- Upper Lip Raise Short expressions Count ( $< 0.25$  sec)
- Lip Suck Threshold
- Lip Suck Frames  $\geq$  Threshold
- Lip Suck Time Percentage
- Lip Suck Long expressions Count ( $\geq 0.25$  sec)
- Lip Suck Short expressions Count ( $< 0.25$  sec)
- Lip Press Threshold
- Lip Press Frames  $\geq$  Threshold
- Lip Press Time Percentage
- Lip Press Long expressions Count ( $\geq 0.25$  sec)
- Lip Press Short expressions Count ( $< 0.25$  sec)
- Mouth Open Threshold
- Mouth Open Frames  $\geq$  Threshold
- Mouth Open Time Percentage
- Mouth Open Long expressions Count ( $\geq 0.25$  sec)
- Mouth Open Short expressions Count ( $< 0.25$  sec)
- Chin Raise Threshold
- Chin Raise Frames  $\geq$  Threshold
- Chin Raise Time Percentage
- Chin Raise Long expressions Count ( $\geq 0.25$  sec)
- Chin Raise Short expressions Count ( $< 0.25$  sec)
- Smirk Threshold
- Smirk Frames  $\geq$  Threshold
- Smirk Time Percentage
- Smirk Long expressions Count ( $\geq 0.25$  sec)
- Smirk Short expressions Count ( $< 0.25$  sec)
- Lip Pucker Threshold
- Lip Pucker Frames  $\geq$  Threshold
- Lip Pucker Time Percentage
- Lip Pucker Long expressions Count ( $\geq 0.25$  sec)
- Lip Pucker Short expressions Count ( $< 0.25$  sec)
- Cheek Raise Threshold
- Cheek Raise Frames  $\geq$  Threshold
- Cheek Raise Time Percentage
- Cheek Raise Long expressions Count ( $\geq 0.25$  sec)
- Cheek Raise Short expressions Count ( $< 0.25$  sec)

- Dimpler Threshold
- Dimpler Frames  $\geq$  Threshold
- Dimpler Time Percentage
- Dimpler Long expressions Count ( $\geq$  0.25 sec)
- Dimpler Short expressions Count ( $<$  0.25 sec)
- Eye Widen Threshold
- Eye Widen Frames  $\geq$  Threshold
- Eye Widen Time Percentage
- Eye Widen Long expressions Count ( $\geq$  0.25 sec)
- Eye Widen Short expressions Count ( $<$  0.25 sec)
- Lid Tighten Threshold
- Lid Tighten Frames  $\geq$  Threshold
- Lid Tighten Time Percentage
- Lid Tighten Long expressions Count ( $\geq$  0.25 sec)
- Lid Tighten Short expressions Count ( $<$  0.25 sec)
- Lip Stretch Threshold
- Lip Stretch Frames  $\geq$  Threshold
- Lip Stretch Time Percentage
- Lip Stretch Long expressions Count ( $\geq$  0.25 sec)
- Lip Stretch Short expressions Count ( $<$  0.25 sec)
- Jaw Drop Threshold
- Jaw Drop Frames  $\geq$  Threshold
- Jaw Drop Time Percentage
- Jaw Drop Long expressions Count ( $\geq$  0.25 sec)
- Jaw Drop Short expressions Count ( $<$  0.25 sec)

## Appendix 6: List of Full Parameters of Eye tracking data - Fixation

- Study Name
- Respondent Name
- Respondent Gender
- Respondent Age
- Respondent Group
- Gaze Calibration
- Stimulus Label
- Stimulus Start
- Stimulus Duration
- Fixation Index
- Fixation Index by Stimulus
- Fixation X
- Fixation Y
- Fixation Start
- Fixation End
- Fixation Duration
- Fixation Dispersion
- Fixation Type
- AOI Intersections
- AOI Label
- AOI Type
- AOI Group
- AOI Instance
- AOI Instance Start
- AOI Instance Duration
- Fixation Index by AOI
- Dwell Index (on AOI)
- D2-bad-graylie-evaluation active
- D2-bad-lie-evaluation active
- D2-bad-truth-evaluation active
- D2-good-graylie-evaluation active
- D2-good-lie-evaluation active
- D2-good-truth-evaluation active
- Judgement active

## Appendix 7: List of Full Parameters of Eye tracking data – Saccade

- Study Name
- Respondent Name
- Respondent Gender
- Respondent Age
- Respondent Group
- Gaze Calibration
- Stimulus Label
- Stimulus Start
- Stimulus Duration
- Saccade Index
- Saccade Index by Stimulus
- Saccade Start
- Saccade End
- Saccade Duration
- Saccade Amplitude
- Saccade Peak Velocity
- Saccade Peak Acceleration
- Saccade Peak Deceleration
- Saccade Direction
- Saccade Type
- AOI Intersections
- AOI Label
- AOI Type
- AOI Group
- AOI Instance
- AOI Instance Start
- AOI Instance Duration
- Saccade Index by AOI
- Dwell Index (on AOI)
- D2-bad-graylie-evaluation active
- D2-bad-lie-evaluation active
- D2-bad-truth-evaluation active
- D2-good-graylie-evaluation active
- D2-good-lie-evaluation active
- D2-good-truth-evaluation active
- Judgement active