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A COGNITIVE APPROACH TO DECEPTION DETECTION: MULTIMODAL RECOGNITION OF PREPARED LIES

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ABSTRACT

Lying is an activity that every human being practices daily. We could say deception has evolved to become a fundamental aspect of human interaction. Despite the prolonged efforts in many disciplines, we can still affirm there has been no such finding as a Pinocchio's nose. (Vrij, 2008).

This work proposes a new approach to deception detection, based on finding significant differences between liars and truth tellers through the analysis of their behavior. This is based on the combination of three factors: cognitive load manipulation, multimodal data collection, and t-pattern analysis.

The first one is a technique that has already been used in previous studies on deception (Vrij, Fisher, Mann, & Leal, 2008) to enlarge the differences between lie and truth.

The second factor, multimodal approach, has been acknowledged in literature about deception detection and on several studies concerning the understanding of any communicative phenomenon.

We believe a methodology such as T-pattern analysis (third factor) could be able to get the best advantages from an approach that combines data coming from multiple signaling systems. In fact, T-pattern analysis is a new methodology for the analysis of behavior (Magnusson, 2000; 2005) that unveil the complex structure at the basis of the organization of human behavior.

We conducted two experimental studies.

Results showed how T-pattern analysis allowed to find significant differences between truth telling and lying even without operating any kind of cognitive load manipulation.

In terms of general impact and anticipated benefits, this project aims at making progress in the state of knowledge about deception detection, with the final goal to propose a useful tool for the improvement of public security and well-being.

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La prima dedica va ai miei genitori, per un sostegno che è iniziato molto prima di tutto questo e che proseguirà oltre, quando tutto questo sarà un ricordo.

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INTRODUCTION

"Man is not what he thinks he is, he is what he hides."
André Malraux

Let's talk about numbers. Turner, Edgley, and Olmstead (1975) estimated that 62% of the statements in everyday general conversations could be somehow classified as deceptive. DePaulo and her colleagues employed a one week diary study to record people's everyday communication, specifically deceptive communication (DePaulo, Kashy, Kirkendol, Wyer, & Epstein, 1996). Their results suggests that people tell approximately two lies per day on average and that approximately 20% to 33% of our daily interactions are deceptive. On average, participants lied in one out of every four of their social interactions, and they lied to 34% of all the people they interacted with over the week. More lies (around 50%) were self-serving than told in the interest of others (around 25%). Most lies (67%) were outright lies, and more lies were told for psychological reasons (around 60%) than for materialistic reasons (around 40%). Similar to Depaulo 's findings, Hample (1980) reports that people are likely to lie 13.3 times per week on average which is 1.9 times per day. Camden, Motley, and Wilson (1984) focus exclusively on white lies and average 16 times over a two week period, that will be, 1.14 white lies per day. Serota, Levine, and Boster (2010) report an average of 1.65 lies per 24 hour period. These data have be supported in two other empirical studies (George & Robb, 2008; Hancock, Thom-Santelli, & Ritchie, 2004). With a similar methodology, Hancock et al. (2004) observe 26% of our everyday communication involving some form of deception, while George and Robb (2008) estimate that 22% to 25% of our daily communication might be deceptive.

Even though percentages can slightly change among different studies, we can be sure about one thing: deception is a ubiquitous phenomenon. Lying is an activity that every human being practices daily. We could say deception has evolved to become a fundamental aspect of human interaction (O'Sullivan, 2003; Trivers, 2011).

Given the pervasiveness of this phenomenon, the accurate detection of deception in human interactions has long been of interest across a broad array of contexts and disciplines. Neuroscience, psychology and communication sciences come first, and because of the consequences related to deception, it holds obvious relevance for the realms of business, politics, jurisprudence, law enforcement, and national security.

Despite the prolonged efforts in all these disciplines, focused mainly in the last 30 years, we can still affirm there is no such thing as a Pinocchio's nose. (Vrij, 2008).

The aim of this work is to propose a new approach to deception detection, which would allow finding significant differences in behavior between liars and truth tellers. This approach is based on the combination of three general factors: cognitive load manipulation, multimodal data collection, and t-pattern analysis.

The first part of this thesis includes an analysis of literature; the first chapter focuses around theories at the foundation of deception as a communicative phenomenon, framing this work within the Deceptive Miscommunication Theory (Anolli, Ciceri, & Riva, 2001). The second chapter offers a review of studies about deception detection and cues to deception currently known, giving a distinction between what has been done on the basis of neuro-physiological data and what has been done on the basis of behavioral indicators.

The second part of the thesis is dedicated to the methodological approach. Each of the three factors will be examined individually. In chapter 3, we will discuss cognitive load manipulation, showing there are two main research branches, which differentiate themselves for the kind of manipulated cognitive load: intrinsic cognitive load attains to the mere cognitive load approach, where manipulation consists of making the act of lying harder (e.g. reverse chronological order); extraneous cognitive load attains to the imposing cognitive load approach, where manipulation is obtained by adding a different task, thus limiting available cognitive resources (dual task procedure).

In chapter 4, we will describe the advantages of multimodality in the study of communication in general and of deception as a communicative strategy. Furthermore, a review of literature will show how in deception detection, the best results have been collected considering more than one "mode" (or system) at a time.

Chapter 5 is dedicated to the presentation of a new methodology for the analysis of behavior, t-pattern analysis, a mathematical approach that may be particularly suitable for defining and detecting repeated temporal patterns in deceptive behavior. T-pattern detection was developed by Magnus S. Magnusson (2000; 2005; 2006) to find hidden temporal and sequential structures in behavior. The pattern type and algorithm were developed basing on the assumption that complex streams of human behavior have a sequential structure that cannot be fully detected through unaided observation or with the help of standard statistical and behavior analysis methods. Given that observational records of human behavior have a hidden temporal sequential structure, an analysis tool that can discover and describe this structure will enhance understanding of the behavior being studied. In our case, we think this approach might be useful to find differences in patterns related to truth tellers and liars' behavior. This could overcome some difficulties such as, for example, the ability of skilled liars to control most of their behavior (one cannot control what he/she is not aware of).

The third and final part of this thesis is dedicated to the application and verification of the goodness of this methodological approach, through two experimental studies. Chapter 6 depicts the results of the first study, a pilot created to verify if reverse chronological order could have been an adapt method of cognitive load manipulation for our approach, to define an appropriate coding grid, and to find out if there were differences in t-patterns related to people that are lying or telling the truth.

Chapter 7 is dedicated to the results of the second study, in which we used a dual task procedure to manipulate cognitive load, modified the coding grid and enlarged our sample. Furthermore, we added an analysis of nonverbal cues of disfluency, analyzing its distribution through NOOJ software (Elia, Vietri, Postiglione, Monteleone & Marano, 2010; Silbertzein, 1993, 2007; Vietri, 2008).

In the conclusions, a general discussion of the achieved findings (such as, elements of innovation and methodological implications) are exposed. Finally, some indications for further research and expected impact are briefly discussed.

Finally, in terms of general impact and anticipated benefits, this project aims at making an advancement in the state of knowledge about deception detection. It is hoped that the presented methodological approach could help in discriminate between lie and truth, with the final goal to propose a useful tool for the improvement of public security and well-being.

PART 1:

THEORETHICAL BACKGROUND

The first part of this work is dedicated to an analysis of literature concerning the theories that tried to explain deception as a communicative phenomenon (chapter 1), and the progress reached so far from scholars in the domain of deception detection (chapter 2).

In chapter 1, we will focus on this work's reference theory, the DeMiT, putting it in relation with the two other fundamental theories, the Information Manipulation Theory (McCornack, 1992; McCornack, Levine, Solowczuk, Torres, & Campbell, 1992; Lapinski, 1995; McCornack, 1997), and the Interpersonal Deception Theory (Buller & Burgoon, 1996; Burgoon, Buller, Guerrero, Afifi, & Feldman, 1996). We will outline common aspects and differences. We will then investigate the role of intention and give a closer look to what lying means and how many ways there are of doing it.

The second chapter will be focused on deception detection, giving an outlook of how many and what kind of cues are currently known, and which are the methodologies and tools used to detect them. We will talk about physiological approach, studies related to verbal cues and the research area related to nonverbal and paraverbal cues.

CHAPTER 1: BACKGROUND

In more than 30 years of study about deception and lying, most of the research and the theoretical effort of scholars has been devoted to the analysis of communicative processes and performances underlying deceptive messages, even though there is not a global and viable theory on deceptive communication now. However, it is worth noting that great advances in the right direction have been made in this field, in the attempt to understand the distinctiveness of deceptive communication processes and also, more recently, the commonalties with default communication. Among the various theoretical models formulated by scholars, this paragraph discusses the Information Manipulation Theory (IMT) proposed by Lapinski (1995), McCornack (1992), McCornac et al., (1992); the Interpersonal Deception Theory (IDT) advanced by Buller and Burgoon (1996), and Burgoon et al. (1996); and the DeMiT (Anolli, Ciceri, & Riva, 2001).

1.1 THEORIES ABOUT DECEPTION

Information Manipulation Theory (IMT) is a framework that describes the different ways information can be manipulated in order to accomplish deceit (Burgoon et al., 1996). According to this model, the observable variations within the deceptive message design, reflect a continuum of a covert-to-overt misrepresentation of information, in which relevant information serves as an anchor and the explicit falsification of truthful information as the other, as it is shown by Metts (1989). The IMT is based on Grice's Co-operation principle (1981) and its four maxims (Quality, Quantity, Relevance, and Manner), considering deception as arising from covert violations of one or more of these maxims governing conversational exchanges. The IMT affirms that individuals constantly monitor the information they disclose, including everyday conversations, along four different primary dimensions: *amount*, *veracity*, *relevance*, and *clarity*. The result is a potentially indefinite range of specific deceptive message forms.

These dimensions form the basis for inferential processing underlying conversational sense-making. Deceptive messages are "deceptive" in that, although they deviate from the principles of conversational understanding, these departures remain veiled. In particular, research proposed by Ekman (2001) and Metts (1989) has showed that deception can be fabricated by manipulating the amount of information conveyed, the veracity, the relevance, as well as, according to Bavelas, Black, Chovil, and Mullet (1990), McCornack et al. (1992), and Yeung, Levine, and Nishiyama (1999), the clarity of information.

To sum up, according to IMT, the deceptive message derives from speakers "transforming" relevant information, although the theory fails to explicate this purported transformation process and, as Jacobs, Dawson, and Brashers (1996) pointed out, it confuses three distinct issues: the production, the features and the interlocutor's interpretation of the deceptive message.

On the other side, scholars like Buller and Burgoon (1994), Burgoon and Buller (1994), Burgoon et al., (1996), Burgoon, Buller, Dillman, and Walther (1995), Burgoon, Buller, and Guerrero (1995), Burgoon, Buller, Floyd, and Grandpre (1996), and Burgoon, Buller, White, Afifi, and Aileen-Buslig (1999) have developed the *Interpersonal Deception Theory* (IDT), which involved a great amount of work and research on the analysis of the communicative patterns of deception. IDT follows a strategic approach to deception comprehension. Buller, Strzyzewski, and Hunsaker (1991) said: *"The [deceptive] conversation is characterized by a series of moves and countermoves, and deception's ultimate success or failure is affected by the skill of both communicators to see through the multiple layers of meaning and react in ways which further their goals"* (p. 28).

Within this perspective, Buller and Burgoon (1994) make a distinction between *strategic* and *non-strategic communication* in deception. Strategic (or intentional) patterns in deception are those manipulated by deceivers with the goal of presenting themselves as truthful and in a believable manner. Deceivers, in this case, know that deception can produce detection cues; therefore, they will attempt to use a strategy that gives an honest impression through communicative signals thought to be indicative of veracity. The non-strategic communication in deception is related to unintentional *leakage cues*; deceivers, in this case, are unaware they are revealing deception, or unable to control themselves in preventing deception detection (cues will be discussed further in the next paragraph).

Therefore, IDT sees the deceiver's communication as a balance between intentional and unintentional (involuntary) signals: if the former prevails, the deception succeeds, whereas, if the latter takes priority, failure is more likely. As a consequence, IDT seems to conceive the deceptive exchange as a battle field, in which the deceiver aims to make strategic communicative signals in an intentional and consistent way to convince the interlocutor, who, however, aims to detect the deceiver by scrutinizing his/her behavior and communicative style. According to DePaulo, Ansfield, and Bell (1996), despite extensive research and numerous theoretical assumptions, IDT also fails, like IMT, at explaining the production mechanisms responsible for deceptive message encoding, and the cognitive processes implicated in deceptive message interpretation.

Both IMT and IDT risk building a sort of "mythology" about deception as a separate communicative channel, characterized by distinct and specific verbal and nonverbal features.

The aim of the present chapter is to overcome this deception mythology and to offer a viable model which can explicate the main characteristics of deceptive communication and the local management of the deceptive message in its different expressions. The theoretical domain in which we move is the *miscommunication as a chance theory* (MaCHT), proposed by Anolli et al. (2001). According to the perspective herein followed, deception is a kind of miscommunication and can be seen as a *chance* in communication terms, since deceptive miscommunication greatly enhances the degrees of freedom at the communicator's disposal. It represents another route to express the speaker's sensations, thoughts, beliefs, emotions, and desires; likewise, at the communication level, having the chance of hiding, omitting, concealing or, simply, blurring information might be a considerable advantage. After all, truth is not a matter of black or white. Deceptive communication may be an opportunity both in a Machiavellian, opportunistic sense and in an everyday relational situation.

Within this perspective a model called the *Deceptive Miscommunication Theory* (DeMiT) has been proposed. This theory sees deceptions as an articulated and complex miscommunication act, an emblematic pattern of adaptive behavior in interpersonal relational management, with the aim of influencing others' beliefs, as outlined by Bond, Omar, Pitre, Lashley, Skaggs and Kirk (1992), and by Buller and Burgoon (1994), According to it, a deceptive miscommunication theory should be included in a general framework capable of explaining the default communication; therefore, deceptive miscommunication is neither an alternative to truthful communication, nor an exception nor yet a violation regarding a standard paradigm of default communication. Regarding deceptive miscommunication, this theory states it is not a homogenous communication, but a heterogeneous one, involving different kinds of deception and deceptive message features. It is managed by an intentional stance characterized by an internal gradation: these degrees of intention serve to arrange and monitor a deceptive message design suitable in a given situation and a contingent relational web. It is therefore context-bound, requesting a "local management" of conversational exchanges, because every context is constructed *in situ*; here a distinction may emerge between naive ("bad") deceivers and skilled ("good") ones.

The deceptive message follows the same mechanisms and processes of mental planning and execution as the default communication message.

Deceptive miscommunication, like default communication, uses different kinds of linguistic and nonverbal expressions, although they may be qualified by distinctive communication patterns in certain circumstances. It is interesting to note that the literature offers many definitions of deception and lies. These can differ, for example, by whether the liar's intentions are considered. According to this theory, the *intention to lie* is the essential feature of deceptive communication, as it is shown by Sweetser (1987), and Anolli, Balconi, and Ciceri (1994).

In the next paragraph we'll take a closer look on the role played by intention in producing a deceptive message, and how it contributes to its definition.

1.2 INTENTION

According to the prototypical perspective proposed by Coleman and Kay (1981), a lie is defined by three basic features: the *falsehood* of the content of the message, the *awareness* of such falsehood and the *intention* to deceive the interlocutor. But falsehood is not always necessary to produce a deceptive message, as you can tell a lie by telling the truth. Moreover, you can tell a falsehood by lying, or by error. A person who mistakenly makes a false statement does so unknowingly (since they think they are telling the truth) and successively learns the truth; instead, when they deliberately tell a lie, the person knows the truth first, and then tells the lie.

Speaking of intention is a delicate subject. As Anolli and colleagues (2001) pointed out, we have to consider different kinds of intention: referential, informative, and communicative, as well as the intentional gradation. Intentional stance is a continuum in the communicative process. Intentions are directly proportional in their strength to the information conveyed by the message, as it is outlined by Jaszczolt (1999, p. 68).

According to the DeMiT, there are different layers of intention in deceptive miscommunication. C*overt (hidden) intention* (the speaker intends to deceive the addressee by manipulating the information, but this intention must not be revealed) is one of these intentional layers. Another layer is the *overt (ostensive) intention* (the speaker intends to convey the manipulation of information to the addressee). This second intentional layer is, in its turn, twofold: it must be made of an *informative intention* (the speaker wants to give the addressee the manipulated information as if it were true). The second 'fold' of this layer is occupied by the *"sincerity" intention* (the speaker wants the addressee to believe that what he has said is true, in order to respect the Sincerity Rule of Searle (1979): "I want you to believe that I believe what I am saying to you").

Therefore, deceptive communication should require at least a second-order intentional system and in certain cases (especially in prepared lies), a third-order intentional system. In this second-order intentional layer we have to make another distinction, between the *deception family* and the *joke family* (which involves irony, teasing, pretense, sarcasm, parody, banter, etc.). While communications that are part of the deception family require for the speaker to intend to deceive his/her interlocutor, messages that are part of the joke family require the speaker to intend to be disbelieved, not to deceive. The speaker's intention to deceive is therefore defined in terms of what the speaker *wants* the addressee to *think*. The deceitful speaker wants the listener to believe that what he or she is saying is true, while the joking speaker wants the listener to know that his or her message is false.

According to the DeMiT, deceptive miscommunication is not the psychological counterpart of truthful communication, and it is not a separate communicative style needing a dedicated message-production mechanism. *Intentional gradation*, intrinsic aspect of any communicative act, can also manage different kinds of deceptive messages, from white lies to prepared and bold-faced ones. The framework of deception as a miscommunicative act implies an increase of the degree of freedom for the speaker, who is able choose a definite path of message design according to context expectancies and cultural standards.

Moreover, intentional system and gradation operating in deceptive miscommunication produce a sort of *intentional opacity*: except for bold-faced lies, a person can hide his or her deceptive act as a result of lack of information, a mistake, poor judgment, a moment of bewilderment, etc. This way, the deceiver can dispose of a face-saving strategy.

In this perspective, one can resort to a deceptive message in order to acquire or protect one's own resources (money, time, possessions, privacy, etc.), or to manage the relationship with a partner (initiate, continue, or avoid interaction; avoid conflict and embarrassment, avoid punishment, leave take, avoid self-disclosure, etc.), or else to maintain or enhance self-esteem (save one's face, improve one's social position, increase one's social desirability, etc.). Goffman (1974) states these motives are part of the *benign fabrication* in deceptive acts. On the contrary, Goffman described different motives as *exploitative* fabrication. One of these deceptive motives can be represented by a deceptive message with the purpose of gaining an advantage at the expense of other people, manipulating or harming them. Revenge, vindictiveness, retaliation, sabotage, and hatred can serve as examples of exploitation and malevolent deception. These and other indefinite numbers of motives underlying deception confirm the flexibility and variability of deceptive communication as context-bound and dependent on the contingent relational web.

Other definitions of deception and deceptive acts have been given over the past 30 years. Many of them appeal to the *intentional* aspect of the communicative act as discriminative. Ekman (2001), for example, defines deception as "a deliberate choice to mislead a target without giving any notification of the intent to do so." Vrij (2008) claims that this definition is incomplete, since liars sometimes fail to mislead. Hence, Vrij defines deception as "a successful or unsuccessful deliberate attempt, without forewarning, to create in another a belief which the communicator considers to be untrue."

We have talked about the role of intention in defining a lie; in the next paragraph, we'll see how intention is essential in the different ways of deceiving as well, understanding why it is more accurate to talk about a family of lies, rather than deception on its own.

1.3 FAMILY OF DECEPTIVE ACTS

Deception in the DeMiT, along with the MaCHT perspective (Anolli et al., 2002), is considered as a "family" of miscommunication phenomena and processes. In this "family", we consider pathological deceptiveness and self-deception, prepared (mainly constructed to avoid punishment) and unprepared lies (produced to manage unexpected situations), pedagogic lies (the ones we could tell a child for reassurance) and white lies (aimed at managing a face-threatening situation for the deceived). For this reason, truthfulness and falsehood are not always considered as a dichotomy separated by a definite line because they blend together in several situations.

In particular, crossing the broad distinction between "having the interlocutor believe the false" and "not having the interlocutor believe the true", we obtain four deceptive "subfamilies". The *omission* family, defined in situations where the speaker omits to give the addressee some information that he/she thinks or knows is relevant to the addressee's goals. *Concealment* happens when the speaker withholds and hides some information by giving the addressee some other divergent/diversionary information, which is true but irrelevant, in order to maintain false assumptions in him/her. The third deceptive subfamily or 'act' consists of *falsification*, when the speaker deliberately conveys information to his interlocutor that he/she believes to be false. The last component of these subfamilies is *masking*: in this case, the speaker withholds some relevant information by giving the addressee some other false information.

Lies can be told by telling the truth, such as in the case of the half-truth, when the speaker only refers part of the truth, or tries to minimize the truthful part of his communication. Continuing this analysis of the deception 'family', exaggeration is another case of deceptive message, where the speaker provides the interlocutor with more information than necessary for the truth to come out.

Moreover, truthful messages can be used to deceive by causing deceptive implications on the grounds of false presuppositions, as it is outlined by Jacobs et al., (1996), and by Castelfranchi and Vincent (1997). In general, the different kinds of deceptive forms here mentioned are covered by the main distinction proposed by Chisholm and Feehan (1997): deception by *commission* and deception by *omission*.

Deceptive "subfamilies" (and other related communicative phenomena) do not constitute "deception types" in the DeMiT, because such a title would mean the acceptance of a priori taxonomy, where deception categories would have to be discrete and distinct, separate from each other by clear, definite and inflexible boundaries. According to DeMiT, there is a continuum among the deceptive "subfamilies": as Wittgenstein (1958) said, there is "a resemblance of family", in which the boundaries are fuzzy and vague, even though this "resemblance" does not deny the presence of great differences in the deception system.

In this chapter we framed our work in a reference theory, DeMiT, and we gave a definition of what we mean by deception, mostly focusing on how this communicative phenomenon is not separated or in a univocal relationship (and mutually exclusive) with truth telling.

The next chapter will discuss what are the cues, techniques and tools that have been used until now to detect deception.

CHAPTER 2: DECEPTION DETECTION

Although deception is a common and frequent phenomenon, humans are poor deception detectors. A meta-analysis of 120 deception detection studies carried from 1943 to 2000 concluded that humans could successfully discriminate between truths and lies only with a rate of 54% (DePaulo et al., 2003). This low accuracy in detecting deception is determined, in first place, by the so-called "truth bias", i.e. the fact that people tend to believe that what others say is true (Ekman, 2001; Feeley & Young, 1998; Levine, Kim, Park, & Hughes, 2006). Many people believe in cues that do not indicate deception (e.g. Vrij, Edward, Roberts, & Bull, 2000), according to stereotypes that are linked to deception by "common sense" (e.g. not looking in the eyes of the interlocutor). Further, many people have a demeanor bias. That is the tendency to think some people look like deceivers and others look like truth tellers (Zuckerman, DeFrank, Hall, Larrance, & Rosenthal, 1979). Demeanor bias can interfere with perception of actual cues to deception because people could judge some individuals as liars and others as truth tellers irrespective of how those individuals behave themselves (Bond, Omar, Mahmoud, & Bonser, 1990). Truth bias, reliance on non-indicative cues, and demeanor bias all hamper laypeople's ability to detect deception. For these reasons, a wide variety of approaches to discover deceptive statements has been tried. They can be very different from each other, but all of them aim to identify some cues of deceptiveness and to verify their correlation with deceptive or truthful communication.

Testing the correlation between cues and deception implies to establish the ground truth that is object of deception. This depends on the context in which the deceptive communication takes place, and hence determines the methodology of the study and the application field.

Present day, the range of clues that can be object of investigation is wider (Vrij, 2008). In these chapters, we will analyze literature about deceptive communication by dividing it in two main branches:

- Studies based on physiological variables and in particular on neuro-imaging techniques;
- Studies focused on Nonverbal behavior. Nonverbal behaviors can be divided into two broad classes: nonverbal visual behaviors (e.g., facial expressions or bodily behaviors) and paraverbal or vocal behaviors (accompanying factors of speech, such as pitch, pauses, or hesitations).

Clearly, we have not mentioned the large part of literature that concerns studies about verbal behavior. We have made this choice because such a large research domain, in order to be treated with accuracy and rigor, it would necessitate a research work of its own.

In the following sections, the two methodological approaches mentioned above will be discussed, all applied to field and laboratory studies.

2.1 STUDIES ON NEURO-PHISYOLOGICAL CUES

In this paragraph, we will talk about the main instruments used to detect deception, starting from neuro-physiological parameters.

The Polygraph

The polygraph is a device that records Electro-Dermal Activity (EDA), blood pressure, and breath, which are assumed to be associated to deception. This association can be of two different kinds, which lead to two different strategies in the use of polygraph: the *concern approach* and the *orienting reflex approach* (Vrij, 2008). The concern approach relies on the assumption that the polygraph can be employed to detect signs of stress, which are supposed to be related to deception. Such studies are mainly performed in criminal investigations, with the use of the Comparison Question Test (CQT) (Backster, 1962, 1963; Raskin, 1979, 1982, 1986; Reid, 1947), an interview protocol in five phases aimed to check the bodily reactions of the subjects to crime-related and different kind of control questions. According to relatively old (Brett, Phillips, & Beary., 1986) and more recent studies (Stern, 2003), in this setting the accuracy of the polygraph in detecting deception can vary from 50% to 95% (Simpson, 2008).

The orienting reflex-based polygraph tests are based on the assumption that an orienting response occurs when someone faces a personally significant stimulus (Vrij, 2008). Orienting reflexes can be detected by polygraph through the Guilty Knowledge Test (GKT), developed by Lykken (1959; 1960; 1988; 1991; 1998). Vrij (2008) showed that field studies achieve from 76% to 88% of accuracy in identifying liars. Above all, between 1% and 6% of innocent subjects were misclassified.

Voice Stress Analysis (VSA)

The assumption of *Voice Stress Analysis* (VSA), similarly to what happens with the polygraph tests, is that telling lies is more stressful than telling the truth (Gamer, Rill, Vossel, & Gödert, 2006). The speech and its characteristics of intensity, frequency, pitch, harmonics, and so on are considered in order to detect signs of stress in the voice. This method allows collecting data covertly and not invasively. However, according to Vrij (2008), voice stress analyses can be inaccurate in detecting truths and lies. Also Elkins, Burgoon and Nunamaker (2012) pointed out how commercial software for vocal analysis focuses on this technology, not updated with the current full vocal spectrum systems. Investigations conducted with full spectrum vocal analysis software found it unable to detect deception above chance levels (Damphousse, Pointon, Upchurch, & Moore, 2007; Haddad, Walter, Ratley, & Smith, 2001).

Thermal Imaging

Thermal Imaging is a technique developed by Pavlidis and colleagues and became notorious after a publication in the scientific journal *Nature* just few months after the September 11 attacks (Pavlidis, Eberhardt, & Levine, 2002). It relies on the assumption that subjects, when they lie, present an instantaneous warming of the skin around the eyes, which is a sign of an increased blood flow. Heat detecting high-definition cameras record such response. The advantage of this technique is that it can be employed covertly. Nevertheless, its achieved accuracy has been questioned, as pointed out by Vrij (2008). More recently, this technique has been discussed for use as a lie detection tool at airports (Warmelink, Vrij, Mann, Leal, Forrester, & Fisher, 2011), in an experiment where professional interviewers outperformed the thermal recordings, correctly classifying a higher percentage of truth tellers and liars.

Transcranial Direct Current Stimulation - tDCS

The *tDCS* is a technique based on injecting a constant, weak current into the brain through electrodes. The effects depend on current intensity and polarity. In Italy, a study of Priori et al. (2008) made use of transcranial Direct Current Stimulation (tDCS) in the dorsolateral prefrontal cortex (DLPFC). Results showed that the stimulation of these areas increased the reaction times for deceptive responses, with significant differences compared to the tasks involving truthful or neutral responses. However, a second study by (Karim et al., 2010) used a slightly different paradigm and reported that the stimulation of the anterior prefrontal cortex resulted in faster deceptive responses and in subjects feeling less guilty about lying. These controversial results reflect the need for more studies of this kind.

Functional Magnetic Resonance Imaging - fMRI

One of the most innovative approaches to deception detection relies on modern techniques of neuro-imaging. In particular, functional Magnetic Resonance Imaging, commonly termed 'fMRI', is deeply affecting cognitive neuroscience (Logothetis, 2008). The fMRI measures the changes in blood flow and oxygen consumption in particular brain areas and it has been employed to visualize the neural activity in subjects while they were lying (Langleben et al., 2002). Results showed that there was a neurophysiological difference between the brain activation level in deception and truth conditions and it can be detected with fMRI. Ganis, Kosslyn, Stose, Thompson, and Yurgelun-Todd (2003) and Davatzikos et al. (2005) found that distinct neural networks seem to support different types of deception.

Other researchers are skeptical about the possibility of mapping cerebral areas involved in the production of deceptive statements (Merikangas, 2008; Simpson, 2008). Moriarty (2009) points out that fMRI lie detection is a science 'in its infancy' and the recent studies in the field are still lacking of consistency and reproducibility.

A recent study by Ding et al. (2012) investigated the neural correlates of identity faking and concealment (considered as two separate kind of deceptive acts). Their results suggest that different neural systems associated with both identity processing and deception were involved in identity concealment and faking.

Spence (2008), who believes that the reliability of fMRI lie detection in 'real world' has still to be proven, notices that 'there is a great deal of variation between the findings described and, crucially, there is an absence of replication by investigators of their *own* findings'. According to Simpson (2008), who carried out a careful review of the recent literature related to this topic, 'the technique does not directly identify the neural signature of a lie. Functional MRI lie detection is based on the identification of patterns of cerebral blood flow that statistically correlate with the act of lying in a controlled experimental situation. The technique does not read minds and determine whether a person's memory in fact contains something other than what he or she says it does'. Nevertheless, his opinion is that 'with ongoing research, and likely improvements in accuracy in the laboratory setting, it does not seem unreasonable to predict that fMRI lie detection will gain wider acceptance and, at a minimum, replace the polygraph for certain applications. Regarding the replacement of the polygraph with the fMRI, Vrij (2008) does not agree with Simpson, considering that 'fMRI tests are expensive, time consuming, and uncomfortable for examinees' and therefore concluding that fMRI would be 'worthy of introducing as a lie detection tool in real-life situations if they are more accurate than the alternative techniques available to date. So far, research has not yet shown that the fMRI technique does produce more accurate results than traditional polygraph testing'.

Functional near-infrared spectroscopy – fNIRS

This functional neuro-imaging technique, based on the use of near-infrared wavelengths, measures brain activity through the same principles as the fMRI, the hemodynamic responses (such as differences of oxygen and blood flow) associated with neuron behavior. Its spatial resolution is relatively poorer, but portability and non-invasiveness make possible for the experimenter to interact with participants in a more naturalistic manner. A recent study has investigated the neural correlates already discussed until this moment (Ding, Gao, Fu, & Lee, 2013), confirming activations in prefrontal regions of the brain, and therefore confirming the feasibility of using NIRS technology to study spontaneous deception.

Event-Related Potentials - ERP

Event-related brain waves can be recorded through electroencephalograms (EEGs) (Rosenfeld, 2002). Among these waves, P300s (between 300 and 1000 milliseconds after the stimulus) are responses to personally significant stimuli and, for this reason, they can be used as cue to deception. A recent ERP study showed the existence of a neural marker in the form of an increased amplitude of the N400 component (linked to conscious control processing) in frontal and prefrontal regions of the left hemisphere, between 300 and 400 milliseconds post-stimulus (Proverbio, Vanutelli, & Adorni, 2013). This marker seemed to be independent of the question's affective value.

Vrij (2008) reported the results of several studies applying this technique, showing that the performance of ERP tests is similar to that of GKT polygraph tests: an average of 82.29% of liars correctly classified and of 8.75% of truth tellers misclassified. However the difficulties in finding the opportune stimuli addressed regarding GKT polygraph tests are present in ERP tests as well.

This summary has highlighted how research in this area is quite active and, especially concerning neuroimaging techniques, how it still has a lot to offer and find out. However, results are often contradicting or hard to generalize, given the large variety of used paradigms. Furthermore, many of these techniques are expensive, and their use in research is inevitably limited. For all these reasons, neuro-physiological recordings are not enough on their own. In the next chapter, we'll see how these parameters can be put beside behavioral indexes, supporting multimodality as a winning strategy in deception detection.

2.2 STUDIES ON NONVERBAL CUES

Studies focused on nonverbal cues to deception usually rely on the activity of trained raters who observe and evaluate videos in which liars and truth tellers interact, in order to analyze different kinds of nonverbal behavior. Coding systems are adopted in order to detect frequency, duration and intensity of several nonverbal cues and to compare the results for liars and true tellers.

In this section, we will discuss deception detection based on nonverbal cues. The multi-factor model (Zuckerman, DePaulo, & Rosenthal, 1981) will serve as a theoretical background, analyzing how each factor influences liars' behavior. We will then present a review of the cues tied by a certain level of agreement in literature and which have been shown to be significantly associated with deception, starting from Vrij's work, which synthesized the result of 132 studies and from DePaulo's meta-analysis. In the end, we will discuss some moderator variables, quite relevant for this work, that weigh in the association between deception and nonverbal behavioral cues, discussing Sporer & Schwandt's meta-analysis.

2.2.1 Multifactor Model

Zuckerman et al. (1981) formalized the main theoretical perspectives investigated in deception detection through nonverbal behavior analyses. According to these authors, deception should affect: Arousal, Emotional Reactions, Cognitive Effort and Attempted Behavioral Control.

The first factor, generalized arousal, involved a heightened level of emotion not linked to a specific task or statement that the deceiver performed, which means the broader act of deceiving heightens arousal. The second factor, emotional reactions, included feelings associated to lying, or felt emotion. According to Ekman (1989, 2001), three emotions are usually associated to deception: guilt, fear, and delight. All of them can be different in different subjects and can affect the liars' behavior. The third factor is c*ognitive effort.* Liars have to accomplish several cognitively demanding tasks. Among all, they have to formulate narratives that are different from the truth they know, to monitor their statements' plausibility and to pay attention not to contradict themselves (e.g. Vrij, 2008). The fourth factor, attempted behavioral control, refers to the deceiver's attempts to appear truthful. Deceivers have a stronger need than truth tellers do to appear truthful, because truth tellers might assume that they will be believed. Therefore, liars have to monitor their verbal and nonverbal behavior, in order to result convincing.

Arousal

The notion that lying is associated with physiological arousal can be traced back to ancient times (Kleinmuntz & Szucko, 1982; Trovillo, 1939) and is central for any physiological approach to deception detection (see pag. 24). Kahneman (1973) claimed that whenever faced with an unusual, threatening, or complex situation, individuals experience a greater degree of arousal. Therefore, when people engage in deception, there is a fear or concern that the deceit will be discovered and this concern raises arousal levels, leading to a physiological or behavioral response that can then be measured by an observer. Moreover, the assumption is that physiological responses associated with arousal are rarely subject to control and, therefore, may provide relatively consistent cues to deception (Zuckerman et al., 1981). Consequently, one would expect to see an increase in frequency of signs of autonomic activity (e.g., eye blinks) and of various types of movements, particularly in the extremities (although this was not explicitly stated by Zuckerman and colleagues). Moreover, vocal cues such as speech errors, speech hesitations and increased intensity in voice have been detected in high arousal situations (Ekman, Friesen, & Scherer, 1976; Ekman, O'Sullivan, Friesen, & Scherer, 1991; Vrij, 2000). These behaviors seem to be carried out semi-automatically, almost outside of conscious control. However, other authors argued that these "nervous" behaviors are likely to be controlled by a competent liar. In high-stakes situations, such as police interviews, truth-tellers sometimes demonstrate more nervous behaviors than liars do (Vrij, Mann, & Fisher, 2006), a finding that is counterintuitive to those engaging in deception detection.

Emotional reactions

The affective approach refers to the emotional state emerging when someone is lying. On the one hand, a liar might feel fear of being caught. On the other hand, he or she might feel guilty about lying. Some authors have postulated withdrawal by liars (Miller & Burgoon, 1982), which should result in an orientation away from the receiver (e.g. gaze aversion), and in fewer illustrators. Ekman, Friesen, and O'Sullivan (1988) and Ekman (2001) mentioned another possible emotion, called *duping delight.* This pleasure of cheating is enhanced, for example, when allies of the liar can witness his actions (Ekman et al., 1988). Fear and guilt should be associated with a reduction in eye contact and smiles and an increase in bodily nonverbal behaviors. However, when smiles occur because of embarrassment or as a sign of duping delight, they might increase. Talking about smile, it is relevant mentioning the work of Duchenne (1862/1990), who noted, through the experimental use of electrical stimulation, that voluntary smiles involve upturned lips (*zygomatic major*), but are not accompanied by activation of muscles around the eyes, thus allowing to reveal a "false friend". Using FACS' coding (Ekman & Friesen, 1978), we can translate these results by affirming authentic smile is a combination of action unit 6 (*obicularis oculi*) and action unit 12 (*zygomatic major*), while au12 by itself could possibly indicate a different emotion or an attempt to simulate a smile. Clearly, we can't talk about a direct link between the so called fake smile and deception. If we consider, for example, the cultural norm according to which, especially in western countries, a "courtesy" smile is socially desirable in given situations: we would probably only pull up the corners of our lips if a person were introduced to us during a funeral; even though, as it probably would happen, that smile wouldn't involve the *orbicularis oculi*, we couldn't link it to an attempt to deceive.

By examining hundreds of genuine and falsified expressions of universal emotions in the laboratory context, researchers have found that involuntary leakage of emotion is ubiquitous; no one seems able to falsify emotions without such betrayals on some occasions, most often occurring during negative emotional displays (Porter & ten Brinke, 2008). Emotional leakage is more likely to be present, and lasts longer in masked expression rather than genuine ones, particularly when suppressing an intense, relative to a weak, emotion (Porter, ten Brinke, & Wallace, 2012). Further, masking one's true emotion is associated with increased blinking rate, while neutralizing emotion is linked to decreased blinking in laboratory and high-stakes settings (Leal & Vrij, 2010; Mann, Vrij, & Bull, 2002; Porter & ten Brinke, 2008).

Cognitive effort

Some researchers have argued that deception requires a greater cognitive effort than telling the truth because of higher processing capacity demands (e.g, Miller & Stiff, 1993; Sporer & Schwandt, 2006; Sporer & Zander, 2001; Vrij, 2000, 2008; Vrij, Granhag, Mann, & Leal, 2011; Zuckerman et al., 1981; Vrij, Fisher, Mann, Leal, Milne, & Bull, 2008; Vrij, Fisher, Mann, & Leal, 2006). We will further discuss this point in the next chapter (cf. pag. 39)

Behavioral manifestations of increased cognitive load concern mainly nonverbal vocal cues. In fact, the production of a message in spoken tongue calls for a planning of it, both before its enunciation (strategic planning) and during enunciation (on-line planning) and these two kinds of planning define the characteristics of the message such as fluency, complexity, and accuracy (Wendel, 1997) In particular, fluency concerns the ability of the speaker to produce language in real time, with no pauses or hesitations (Skehan, 1996).

The increase of cognitive load related to deception, limiting available resources to executive system (which need them for a correct planning of the message), provokes the emersion of the so-called disfluency cues, which include slowed speech rate, longer pauses, and increased speech hesitations (e.g., *uhm, ah, ehm*), giving the liar more time to plan and tell a believable story (Vrij, 2005; Vrij & Mann, 2001; Yuan & Ellis, 2003)

Furthermore, the liar may neglect and suppress his body language while preoccupied with the challenges of deception. For this reason, deception is generally associated with fewer hand and arm movements, that usually complement speech to illustrate the narrative content (it also happens in low-stakes laboratory situations with students as participants; DePaulo et al., 2003).

Attempted behavioral control

Elements of the cognitive load experienced during deception may be in part attributed to the liar's attempts to consciously control his/her behavior in an effort to appear honest. This notion presupposes that the sender of the deceptive message has an idea of the behavioral displays presumably raising skepticism about his or her own credibility in the receiver (see also Köhnken, 1990). Consequently, liars will try to display behaviors opposite to those that people believe give a lie away. Specifically, individuals often associate deception solely with increasing (not decreasing) intensity or frequency of certain behaviors (Akehurst, Köhnken, Vrij, & Bull, 1996; Breuer et al., 2005; Granhag & Stromwall, 2001; Stromwall, Granhag, & Hartwig, 2004; Vrij & Semin, 1996) and therefore try to inhibit these behaviors. In this way, deceivers' attempts to inhibit their behavior (e.g., head movements) actually serve as cues to deception because their performance appears rigid and lacking in spontaneity (DePaulo & Kirkendol, 1989; Zuckerman et al., 1981). Moreover, in attempting not to avert his or her gaze from the recipient's eyes, a liar may stare too long and too hard (Mann, Vrij, Leal, Granhag, Warmelink, & Forrester, 2012). Similarly, efforts to avoid excessive fidgeting may result in reduced and overly controlled, rigid body movements (DePaulo et al., 2003; Vrij, 2008). On the other hand, skilled liars may attempt to appear credible by deliberately using illustrators and gestures.

Furthermore, Ekman and Friesen (1969) postulated that some nonverbal channels are more controllable than others. This is referred to as the *leakage hierarchy hypothesis*. Specifically, these researchers postulated that relative to the face, the body is less controllable and therefore a better source of leakage (nonverbal acts that give away a message the sender wishes to hide) as well as of deception cues (nonverbal acts indicating that deception is occurring without revealing the hidden message). Additionally, deception sometimes becomes evident because of so-called channel discrepancies (behaviors are reduced in one channel but not in others).

2.2.2 Cues to deception summary

Vrij (2008) summarizes a set of 132 studies focused on nonverbal cues to deception. The effect sizes found were evaluated according to the criteria suggested by Cohen (1988). Out of the seventeen cues considered, only three were found significant. The first includes hand and finger movements: liars move hands and fingers less than true tellers, with a 'small/medium' effect size. However, Vrij, Akehurst, and Morris (1997) analyzed this variable on 181 subjects, finding that '64% of them showed a decrease in hand/finger movements during deception, whereas 36% showed an increase of these movements during deception. The second is related to Illustrators: liars show fewer illustrators than true tellers, with a 'small' effect size; the third is a vocal cue, the pitch: liars may exhibit a higher pitch of voice than truth tellers, but the effect is small (furthermore, the difference between liars and true tellers is usually a few Hz, and it needs professional devices to be detected);

The overall findings of the studies indicate that many conflicting results have been found (Vrij, 2008). For example, in some studies speech hesitations are more frequent in liars than in true tellers, in others the findings claim the opposite. The pauses in the speech seem to be longer in liars than in true tellers, but not necessarily more frequent. Sporer and Schwandt (2006) found longer latencies in liars than in truth tellers, but also in this case the effect size was small. Gaze behavior does not seem to indicate deception because it is relatively easy to control and people are aware of its importance in communication; thence gaze aversion, despite popular beliefs, cannot be considered an effective marker for deception (Vrij, 2008). In particular, if we are speaking about cues related to emotional reactions and arousal, it is important to notice that not only liars feel intense emotions. Even when clues of emotional reactions can be found, the cause for these emotions could be unclear. Therefore, coherently with Frank, Menasco, and O'Sullivan (2008), behaviors that are indicative of deception can be indicative of other states and processes as well.

Together with the discussed cues, DePaulo et al. (2003) considered around one hundred behaviors, of which only a few were significant (including the three already discussed). They found that, compared to true tellers, liars tend to have a greater pupil dilation (Wang, Spezio, & Camerer, 2010), they appear tenser, have a more tense voice, have their chin more raised, press their lips more, and have less pleasant looking faces. They also sound more ambivalent, less certain and less involved, and make more word and sentence repetitions (Vrij, 2008). However, no cue shows a significance greater than small or medium, and again Vrij concludes that Pinocchio's growing nose does not exist (Vrij, 2008).

2.2.3 Moderators of nonverbal cues to deception

In a meta-analysis study, Sporer & Schwandt (2007) took in consideration different variables as mediators when talking about revealing cues. We'll report the results of their work's core analyses, i.e. the effect of: content of the lie, motivation, preparation and interaction. The article investigates a subset of 11 nonverbal visual behaviors, considered particularly important from the authors in an applied perspective: blinking, eye contact, gaze aversion, head movements, nodding, smiles, adaptors, hand movements, illustrators, foot and leg movements, and postural shifts.

Content of the lie

Two categories have been taken into consideration: lying about feelings and facts and lying about facts only. Participants displayed less eye contact when lying about feelings and facts as compared with facts only. Head movements and deception were positively associated when participants talked about feelings and facts but not when they talked about facts only. At the same time, individuals nodded less when lying about feelings and facts compared with facts only. Participants also displayed significantly fewer illustrators and tended to smile less when lying about feelings and facts than when lying about facts only (participants displayed also more adaptors but the differences between the groups were not statistically significant).

Motivation

Deception under low motivation was associated with less smiling compared with the high-motivation condition. Increases in head movements and decreases in nodding and smiling were detected under lower levels of motivation, whereas hand movements decreased under high levels of motivation.

Preparation

Nodding was negatively associated with deception under short preparation time but became positively associated under medium preparation time. Head movements were recurrent when lying after medium preparation. Moreover, a significant reduction in hand movements was detected when lying under short preparation.

Interaction

Interaction was coded at three levels: no interaction between sender and receiver (e.g talking into a video camera), one-sided interaction (talking with a receiver without questions), and two-sided interaction (with questions and answers by sender and receiver).

For none of the nonverbal behaviors considered significant differences were found. Only nodding seemed to be negatively associated with deception in two-sided communications. Therefore, type of interaction does not seem to moderate the association of deception with nonverbal behaviors.

Gender

The analysis of literature revealed there are very few studies that investigate gender differences in deception. Among them, most focus on differences as lie detectors, while only some take into account gender differences in liars.

About this matter, some researchers believe that men are more effective liars (DePaulo, Stone, & Lassiter, 1985; Geis & Moon, 1981; Zuckerman et al., 1981) or that men will deceive more (Camden, Motley, & Wilson, 1984; Serota, Levine, & Boster, 2010). However, DePaulo et al. (1996) recorded more lies from women in everyday life but it seems that men may tell more outright lies (Carlson, George, Burgoon, Akins, & White, 2004).

Although no gender differences have been found in the frequency of lies (DePaulo, Kashy, Kirkendol, Wyer, & Epstein, 1996), men and women tell different types of lies. Men tell more self-oriented lies than women, whereas women tell more other-oriented lies than men (DePaulo & Bell, 1996; DePaulo et al., 1996; Feldman, Forrest, & Happ, 2002), particularly towards other women. In female–female conversations, equal percentages of lies told (around 40%) were other- and self-oriented. In male–male conversations, self-oriented lies were told about six times more (around 60%) than other-oriented lies (around 10%) were (DePaulo et al., 1996).

Moreover, men are more willing than women to use deception in order to get a date (Eyre, Read, & Milstein, 1997; Rowatt, Cunninghan, & Druen, 1998), and differences also emerge in the types of lie men and women tell during a date (Benz, Anderson, & Miller, 2010; Eyre *et al.*, 1997; Keenan, Gallup, Goulet, & Kulkarni, 1997; Tooke & Camire, 1991; Whitty, 2002). Men tend to lie more frequently about their earning potential whereas women more frequently engage in deceptive acts to improve their physical appearance.

Even less research focused on gender differences in cues to deception as exhibited by men and women. A study by Cody and O'Hair (1983) found that male liars suppressed leg/foot movements and the use of illustrators during deception; when using prepared lies, an increased facial adapting was detected. Contrary to expectations, no gender differences were found for laughter, smiling or for eye contact duration (Cody & O'Hair, 1983).

We believe exploring gender differences in behavioral cues during deception would be an interesting research area. Assuming from the DeMiT point of view, that deception is not an alternative communication form, it comes natural hypothesizing that, if in default communication men and women organize their behavior differently (both verbal and nonverbal), the same should happen during deception (Anolli et al., 2001). Furthermore, as we have seen in this chaper, the variables that influence behavior during deception and weigh in the relationship between behavioral cues and deception are different (e.g. emotional reactions, arousal, and motivation). Therefore, it is reasonable to suppose gender differences could intervene in different displays of behavioral cues.

To sum up, the analysis of literature tells us how few cues have been significantly and undoubtedly associated to deception. The research's results are controversial and the variables intervening within this relationship are several and difficult to control.

However, it seems that clusters of cues could be effective in deception detection. We will discuss this issue in the next chapter.

PART II:
RESEARCH QUESTION AND METHOD

RESEARCH QUESTION

Three essential points emerged from the literature review in the previous chapters:

- An able liar can control and handle most of his/her manifest behavior, making detection of deception very hard. This is a very important point, considering the immediate applications of this kind of research, i.e. what concerns security. It is reasonable to think that a person involved in events that put in danger people's security would have a better than average ability to lie. We can't expect his/her behavior to easily reveal deception cues.
- There's no such thing as a Pinocchio's nose; no cue is unequivocally sufficient to affirm that a certain message is deceptive. The variables influencing the relationship between every indicator and the reason determining it (in our case we would have to assume it is the intention to deceive the interlocutor) are too many, and hardly controllable.
- Human beings are not able deception detectors. They are influenced by many factors; truth bias and false beliefs about deception cues are among them. Furthermore, not everything that is observable can be seen with the naked eye. The aid of technology and advanced informatics tools could be the winning combination in this field of research, allowing to overcome human error.

The objective set in this research, therefore, is to overcome these gaps and find significant and systematic differences in the organization of behavior between people who lie or tell the truth.

To do this, we propose a methodological approach based on the combination of three factors: cognitive load manipulation, multimodal data collection and t-pattern analysis (see Figure 1).

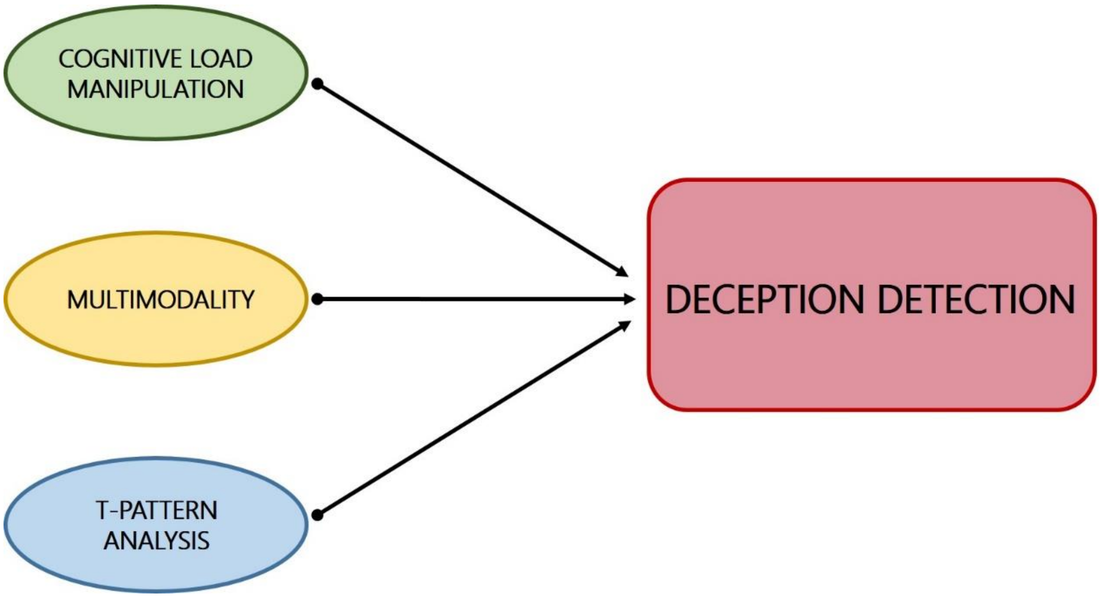

Figure 1. The methodological approach.

In the following chapters we will specifically talk about each of these factors. Chapter 3 will discuss how manipulating cognitive load can elicit differences between truth telling and lying, also when able liars are concerned.

Chapter 4 will show why we think a multimodal approach would be the most effective strategic choice. Chapter 5, finally, will explain a new methodology for the analysis of behavior, the T-pattern analysis. Assuming that behavior is an organized combination of events (or patterns of events) and that this organization is not always visible to the naked eye, t-pattern analysis detects hidden structures (t-patterns), which might help revealing the differences between liars and truth tellers.

CHAPTER 3: COGNITIVE LOAD MANIPULATION

Literature describes two cognitive lie detection approaches, but they both rely on the classic *Cognitive Capacity Theory* (Kahneman, 1973). According to this theory, everyone has a limited amount of cognitive resources at any given time and the cognitive processing ability is a fixed amount of capacity, available for either a single or multiple tasks. The latest research agree that executive working memory resources are the quintessential component of cognitive capacity. Working memory is typically structured as a hierarchically organized system in which specific storage and maintenance components sub serve a central component responsible for the control of information processing (e.g., Baddeley & Hitch, 1974; Cowan, 1995; Miyake & Shah, 1999). It has been shown that general cognitive ability tests primarily reflect central executive capacity (e.g., Engle, Tuholski, Laughlin, & Conway, 1999; Kane, Bleckley, Conway, & Engle, 2001).

In the next paragraphs, we will examine each of the two cognitive load approaches specifically, but first, two key concepts need to be defined. They are both adapted from the Cognitive Load Theory (Merrienboer and Sweller, 2005). *Intrinsic cognitive load* refers to the inherent demands on the cognitive resources of attention and working memory needed to lie well. *Extraneous cognitive load* means any demands on or loss of cognitive resources due to tasks or factors external to the act of lying that makes it more difficult.

3.1 MERE COGNITIVE LOAD APPROACH

The first approach assumes that the mere act of lying generates observable signs of cognitive load (intrinsic cognitive load). As we discussed in previous sections, some researchers argue that increased cognitive load will result in slower response times and recommend examining response times (Walczyk, Roper, Seemann, & Humphrey, 2003; Walczyk, Schwartz, Clifton, Adams, Wei, & Zha, 2005). Others suggest that increased cognitive load results in a decrease in movements and recommend observing hand, foot, and leg movements (Sporer & Schwandt, 2007). This is the traditional cognitive lie detection approach, based on the work of Zuckerman and colleagues (1981). Several authors agree in stating that some aspects of lying contribute to this increased mental load. First, formulating the lie itself may be cognitively taxing. Second, liars are typically less likely than truth tellers to take their credibility for granted (DePaulo et al. 2003; Gilovich, Savitsky, & Medvec, 1998; Kassin 2005; Kassin & Gudjonsson 2004; Kassin & Norwick 2004; Vrij et al., 2006). As such, liars will be more inclined than truth tellers to monitor and control their demeanor so that they will appear honest to the lie detector (DePaulo & Kirkendol 1989), which should be cognitively demanding. Third, because liars do not take credibility for granted, they may monitor the interviewer's reactions more carefully in order to assess whether they are getting away with their lie (Buller & Burgoon, 1996; Schweitzer, Brodt, & Croson, 2002). Carefully monitoring the interviewer also imposes cognitive load. Fourth, liars may be preoccupied by the task of reminding themselves to act and role-play (DePaulo et al. 2003), which requires extra cognitive effort. Fifth, liars have to suppress the truth while they are lying and this is cognitively demanding too (Spence et al. 2001). Finally, whereas activating the truth often happens automatically, activating a lie is intentional and deliberate, and thus requires mental effort (Gilbert, 1991; Walczyk et al. 2003, 2005).

Empirical support to these statements comes from various sources. First, in an examination of high-stake police interviews with real-life suspects, lies were accompanied by increased pauses, decreased blinking, and, for males, decreased hand and finger movements, all of which are signs of cognitive load (Mann et al., 2002). Second, police officers who saw videotapes of suspect interviews reported that the suspects were thinking harder when they lied than when they told the truth (Mann & Vrij, 2006). Third, participants in mock-suspect experiments directly assessed their own cognitive load during interviews and reported that lying is more cognitively demanding than truth telling (Vrij, 2008). Fourth, participants who kept diaries for a week reported that lying was more cognitively demanding than truth telling (Vrij, Ennis, Farman, & Mann, 2010). Fifth, fMRI research has demonstrated that deceiving is associated with activating executive 'higher' brain centres such as the prefrontal cortex (Gamer, 2011).

Obviously, not always lying is more cognitively demanding than truth telling (McCornack, 1997). Perhaps the six reasons given as to why lying is more cognitively demanding could give us insight into when it is more cognitively demanding. That is, lying is more cognitively demanding to the degree that these six principles are in effect.

To sum up, although liars should experience cognitive load more than truth-tellers, the differences between liars and truth-tellers may be relatively small, and perhaps not readily discernable by observers (DePaulo et al. 2003; Zuckerman et al. 1981). Our goal, therefore, was to magnify the differences between liars and truth tellers.

3.2 IMPOSING COGNITIVE LOAD APPROACH

The second approach, more recent, works on manipulate extraneous cognitive load. In fact, an additional cognitive demand is imposed on individuals to enlarge the observable differences between lying and truth-telling. Within this method, we can identify two different threads; in the first, the goal is to make the lie task harder (e.g Vrij et al., 2008;

2011) while the second relies on the dual-task paradigm (Baddeley & Hitch, 1974; Baddeley, 1992).

As regards the former, lie detectors could exploit the increase in cognitive load that people experience when they lie by introducing mentally taxing interventions. People require more cognitive resources when they lie than when they tell the truth to produce their statements, and therefore will have fewer cognitive resources left over to address these mentally taxing interventions when they lie than when they tell the truth. This should result in more pronounced differences between lying and truth-telling in terms of displaying signs of cognitive load (e.g. more stutters and pauses, slower speech, slower response times, less quality details, inconsistencies, fewer movements) when these cognitively demanding interventions are introduced than when such interventions are not introduced (Vrij, 2008). Researchers used many strategies to make deceiving cognitively harder than telling the truth. We are now briefly discussing two of the most widely employed techniques: maintaining eye contact with the interlocutor and recounting events in reverse chronological order.

Lying while having to maintain eye contact with the interlocutor can raise cognitive load and anxiety. Vrij and colleagues (2010) directed some participants to lie to interview questions; others subjects had to tell the truth. Half of those who had to lie were further instructed to maintain continuous eye contact with the interviewer. Observers of videotapes of the interviews were better at discriminating liars from truth tellers when eye contact was maintained, suggesting that it imposed greater cognitive load and anxiety on liars, enhancing the differences between lie and truth and revealing some cues to deception (Vrij et al., 2010).

However, this technique might prove ineffective with Japanese and those of other non-Western cultures, for whom this behavior goes against societal norms. It might induce inordinately high levels of anxiety and be distracting, even for truth tellers (McCarthy, Lee, Itakura, & Muir, 2006).

The temporal order in which events are recalled can magnify cues to deception too. Vrij et al. (2008) directed half their participants to lie and the other half to tell the truth about what happened during a staged event. Some participants of each condition were further instructed to report events in reverse chronological order. Others reported in chronological order only. More cues to deception emerged and were noticed by observers in the reverse order recounting. The authors noted that recalling in reverse order runs contrary to the typical forward chronological encoding of events and thus imposes a heavy load, especially for liars. Vrij, Leal, Mann, & Fisher (2012) extended this technique by asking individuals to lie or tell the truth about a route they took in chronological and in reverse chronological order. More cues to deception again emerged and were noted by observers in the reverse order retelling.

Some criticisms have been leveled against this technique. Clever perpetrators might base their false alibis on episodic memories of actual events, altering details as needed (Sporer and Schwandt, 2007; Leins, Fisher, & Vrij, 2012). The reverse chronological retelling of these liars might then be similar in cognitive load to that of truth tellers doing the same.

On the other hand, techniques under the heading of dual-task paradigm seek to induce cognitive load selectively on liars not making the lie task harder but rather by altering other aspects of the examination procedure or context. Practically, researchers used to ask their subjects to carry out a *secondary task* at the same time as they lie. Because of the additional resources that are needed for telling the lie, people should find this dual tasking more cognitively difficult when they lie than when they tell the truth, and as a result, should perform worse when they lie. Cognitive scientists have long used this research paradigm to determine when different tasks use a common system or pool of resources (Pashler, 1994; Baddeley, 1996).

Meyer and Kieras (1997) evaluated various theoretical accounts of multi-task interference. The one that most of the authors take as a framework for their own research (e.g. Patterson, 2009; Vrij et al. 2008) is the aforementioned Cognitive Capacity Theory (Kahneman, 1973). Its basic assumptions are that (a) attentional capacity is a limited general resource that can be assigned to multiple tasks. (b) The amount of attention allocated depends on the demands of the current activities. (c) Under low levels of task load, attention can easily be divided between tasks, not so when either or both of the tasks are difficult. (d) Finally, attention is controllable and can be allocated dynamically.

Meyer and Kieras (1997) also review the major criticisms of this account. The one most problematic concerns *difficulty insensitivity*: varying the difficulty of a primary task often does not interfere with a concurrent task, which should occur if both are dependent on a central, limited resource. Walczyk, Igou, Dixon, & Tcholakian (2013) ascribe to difficulty insensitivity the findings of Patterson (2009), who found that lying was minimally disruptive of a concurrent math task. In this study, truth tellers followed written instructions to go to the university bookstore, perform specific tasks, and later honestly describe and answer questions about what they did. Liars were shown these instructions but prepared deceptive narratives as if they had been followed, which they later conveyed and answered questions about. During the interview phase, all participants had to perform a concurrent math task. Math response times and accuracies were the dependent measures.

Results showed that dual task interference was minimal. No differences were found for the math task response times, but there was slightly higher math accuracy for truth tellers. Moreover, when interviewees were engaged in a secondary task, observers were slightly more accurate in assessing the veracity of responses and attributed higher loads to liars.

A powerful framework for understanding multi-task interference effect is *Adaptive Executive Control* (AEC; Meyer & Kieras, 1997; Meyer et al., 2002). It overcomes the criticisms of the Cognitive Capacity Theory because it attributes dual task interference to the flexible strategies individuals adopt to fulfill their task priorities as handled by supervisory executive processes. In effect, one task is put on hold while another task higher in priority takes precedence and executes. Finally, AEC explicitly takes account of the constraints in processing imposed by perceptual and motor systems during multi-task performance. For instance, concurrent tasks both requiring verbal responses will naturally interfere. To summarize, the major sources of interference are competition between concurrent tasks for the same perceptual or motor response systems or the executive process performing one task before another due to its higher priority given the performer's goals.

Dual-task paradigm applied to deception detection is innovative, and more research is needed to verify its effectiveness. We believe that the key to obtain the best results is to create a second task that rely on the same cognitive systems (perceptual or motor) employed for the primary task, in our case the lie task. The second task, therefore, will be as more effective as its execution activates the same mechanisms, and loads on the same systems used for creating, processing and telling the specific kind of lie being investigated.

This technique is exposed to a major risk. Because of peoples' keenness to be believed when they lie (DePaulo et al., 2003) or because the simultaneously execution of the two tasks is too hard, it might happen that people will focus their attention primarily on the storytelling task when they lie. Consequently, the predominant differences between truth-telling and lying will occur in the second task, defeating the attempt to decrease the subjects' effectiveness in the deception task.

The next paragraph will concern the second factor and it constitutes our methodological approach, multimodal data collection.

CHAPTER 4: MULTIMODAL DATA COLLECTION

Multimodality is a new and rapidly developing sub-field of communication studies which looks beyond language to the multiple modes of communicating or making meaning, from images to sound and music.

A mode is a socially shaped and culturally given semiotic resource for making meaning. Image, writing, layout, music, gesture, speech, moving images, soundtrack, and 3D objects are examples of modes used in representation and communication (Kress, 2010).

Human conversational interaction is a complex composition of multimodal visually and audibly accessible information. When interacting with others, we rely on cues from communication channels that involve verbal and paraverbal cues (e.g., speech and prosody) as well as nonverbal information. The multiplicity of communication systems (modes) can be seen as a condition for stressing or weakening the communicative meaning, according to the speaker's intention, the interaction with the addressee, and the context of use. In fact, in every communicative act we can determine and find out different verbal, prosodic, mimic, and gesture signaling systems; however, this multiplicity is coordinated by a central system, in order to guarantee the necessary semantic synchrony among the different signaling systems as a condition to get a unitary and consistent message.

These different systems of communication, although autonomous, are not disconnected from each other, but they are mutually connected by interdependence links. The outcomes of such interdependence are various, first of all a great degree of freedom is offered to the speaker, in order to manifest and calibrate his/her own communicative intention as related to the context. In this way, he/she can regulate and shade what he/she intends to communicate to the interlocutor, being able to resort to different communicative registers. Secondly, the different signaling systems converge in a global and unitary communicative action, with a more or less high consistency degree. Moreover, meaning is not connected with a unique and exclusive signaling system but a network of semantic co-relations between different systems constitutes it. Finally, the connection between different and distinctive signaling systems allows us to explain how possible conflicts and contrasts can appear between them, generating semantic loosening so that meaning tends to be confused or even null.

Nevertheless, how different signaling systems come to produce a communicative act that is coherent in itself, since it displays a determinate communicative intention? Such a process of forming a holistic concept from integrating multi- or crossmodal information may be defined as *semantic synchrony*, since their non-random combination and interdependence allow the production of a specific meaning of the communicative act. It influences behavioral performance (Campanella & Belin, 2007; de Gelder & Vroomen, 2000; for review see Koelewijn, Bronkhorst, & Theeuwes, 2010) and neural activation patterns (Collignon et al., 2008; Ethofer, Pourtois, & Wildgruber, 2006; Kreifelts, Ethofer, Grodd, Erb, & Wildgruber, 2007; Pourtois, de Gelder, Bol, & Crommelinck, 2005; van Atteveldt, Formisano, Goebel, & Blomert, 2004; Zeelenberg & Bocanegra, 2010).

The plurality of signaling systems, herein mentioned, together with meaning stability and instability, contributes to explain the wide range of different communicative phenomena in a reasonable and viable way. In the case of default communication, we have communicative acts provided with coherence and unambiguousness, given that the meaning portions of a signaling system are consistently and univocally connected with the meaning portions of other systems. On the other hand, the existence of conflicts and contrasts between meaning portions conveyed by different signaling systems helps to explain different miscommunication forms, like ironic, seductive or deceptive communication.

Like happens in default communication, liars are able to arrange a set of different signaling systems to communicate and make their communicative intentions effective, like language, the paralinguistic system, the face and gestures system, the gaze, the proxemics and the haptic, as well as the chronemic.

Since no diagnostic cue to deception occurs, it could be that a diagnostic pattern does arise when a combination of cues is taken into account (Vrij, 2008).

Several studies showed that clusters of cues could be effective in deception detection. Vrij (2008) claims that, with a combination of four different variables (illustrators, hesitations, latency period, and hand/finger movements) he was able to classify correctly 84.6% of liars and 70.6% of true tellers (Vrij et al., 2000). Frank and Ekman (1997) found similar results; they achieved an accuracy of up to 80% in detecting deception through the observation of microexpressions, but reached an even better performance when taking microfacial expressions and tone of voice into account. In a similar vein, recently Jensen, Meservy, Burgoon, & Nunamaker (2010), focused on cues coming from audio, video and textual data, with the aim of building a paradigm for deception detection via a multi-layered model. These authors take into consideration directly objective indicators (*distal cues*) rather than human observations (*proximal cues*), that they found to not lead to the best performance in detecting deception. They reached a classification accuracy of 73.3%, and claim that deception indicators are subtle, dynamic, and transitory, and often elude a human's conscious awareness. The increased precision afforded by the distal cues may provide additional information that can be used to classify deception directly. This finding demonstrates the effective use of unobtrusive, automatically extracted features in deception detection (Jensen et al., 2010). Other studies have shown that between 71% and 78% of correct classifications were made when the researchers investigated a cluster of behaviors (Vrij, Akehurst, Soukara, & Bull, 2004; Davis, Markus, Walters, Vorus, & Connors; Heilveil & Muehleman, 1989). In other words, more accurate truth/lie classifications can be made if a cluster of nonverbal cues is examined rather than each of these cues separately.

Clustering nonverbal cues of deception brings out some issues that remain unresolved at present. First of all, which kind of behavior should be clustered? Currently, different researchers examine different clusters of behavior, and it cannot be ruled out that a cluster that is effective in pinpointing lying in one situation or group of participants is not effective in another situation or group of participants (Vrij, 2008). Second, is there a criterion for grouping different behaviors into the same pattern? For example, the temporal distance between one cue and another is decisive. How much time must elapse between two cues to consider them as part of the same pattern? Finally, liars sometimes deliberately attempt to appear credible to avoid detection. For example, able liars, or people who are informed about the operating method on nonverbal behaviors, can successfully employ countermeasures to conceal nonverbal cues to deception. If it is known amongst terrorists, spies and criminals which lie detection tools will be used to catch them, they may learn more about these tools and attempt to beat them. If they succeed in doing so, the tools are no longer effective.

Of course, people can easily control only those patterns that are manifest and have a macroscopic nature, easily readable from the outside time by time. However, patterns in behavior are frequently hidden from the consciousness of those who perform them as well as to unaided observers (Magnusson, 2006). As Eibl- Eibesfeldt (1970) argued, "behavior consists of patterns in time. Investigations of behavior deal with sequences that, in contrast to bodily characteristics, are not always visible". Order alone is not a valuable criterion to detect hidden recurrent behavior patterns because deceptive strategies are characterized by a large complexity and by a great variability in the number of behaviors occurring between the liar and his interlocutor. In the next paragraph, a new method for detection and analysis of pattern in behavior will be discussed.

CHAPTER 5: T-PATTERN ANALYSIS

The detection of hidden recurrent action patterns and probabilistic social interaction sequences in natural or relatively unconstrained settings is a common goal of both ethological research (Dawkins, 1976; Montagner, 1978; Tinbergen, 1963) and human interaction research, such as the analysis of turn taking (Duncan & Fiske, 1977). Perceptual grouping of stimuli according to proximity and form was already known from Gestalt psychology (Kohler, 1947). Even though unaided observers often perceive human behavior in interactions as somewhat structured and repetitive, they find it difficult or impossible to specify what kinds of patterns are being repeated or when. Therefore, the approach adopted in this work assumes that the temporal structure of a complex system of behavior is largely unknown, at least consciously.

The kind of pattern proposed below is called a *T-pattern,* a particular kind of temporal pattern or configuration, which, together with the corresponding detection algorithm, might be most readily used in areas close to its conceptual and methodological origin. Behind the pattern definition lie the hypothesis that both hidden and manifest behavior patterns may involve similar relations among their parts. The T-pattern definition, therefore, attempts to abstract some of these relations in order to create an-algorithm for the detection of hidden patterns. Examples of well-known patterns that may serve as models are, for example, standard phrases, which are sequences of words that, in turn, are sequences of phonemes. Patterns with both verbal and nonverbal components include greeting rituals and a multitude of other every day ceremonies, routines, and processes of work and play (for example, a lunch is a pattern). Between the components of a T-pattern, the number and type of behaviors that may occur may vary greatly from instance to instance of the same pattern, which makes the detection of such patterns difficult with methods that depend only on the order or sequence of events.

The corresponding detection algorithm for a T-pattern allows detection of repeated temporal and sequential structures in real-time behavior records. The pattern type and algorithm were developed basing on the assumption that complex streams of human behavior have a sequential structure that cannot be fully detected through unaided observation or with the help of standard statistical and behavior analysis methods. Given that observational records of human behavior have a hidden temporal sequential structure, an analysis tool that can discover and describe this structure will enhance understanding of the behavior being studied.

A generic observational software package called **THEME** has been developed specifically to operationalize T-pattern detection as an analysis process (Magnusson, 1996, 2000). During this process, it considers not only the order of events in behavior, their relative and real timing and sometimes the (internal and/or external) context of the behavior, but also the hierarchical organization of the events. THEME detects complex patterns as combinations of simpler ones, and deals with combinatorial explosions through competition between patterns. Consequently, only the most complete patterns survive and are retained, while all partial patterns are discarded. In this way, THEME detects complex repeated patterns that otherwise remain hidden to the naked eye and are very hard or impossible to detect using other methods. In other words, it is particularly good at detecting complex patterns often buried deep within large amounts of "noise" (other coded events).

Behavior is coded during an *observation period* in terms of the discrete occurrence times of *event types,* where each event type is a particular behavior performed by a particular agent. Behaviors are described in terms of *categories* that are usually behavioral (e.g. smile, run, touch and so forth) but may also be physiological and/or environmental or any mixture of all of these. Each event type occurrence is located at a time unit that is, is a point on a discrete time scale. The choice of categories and time scale must be obviously based on a good understanding of the system being studied, as well as of the T-pattern type and the detection algorithm.

Given a simple *data set* containing multiple occurrences of two different event types, A and B, T-pattern detection (see Figure 2) will take place as follows:

a) THEME tests the null hypothesis that occurrences of A are followed by at least one occurrence of B within a particular approximate distance significantly more often than expected by chance. b) If such an approximate distance is found, its lower and upper limits form a *critical interval* (time window), and the relationship between A and B is called a critical interval relationship. c) For this calculation, THEME assumes as a null hypothesis that A and B are independently distributed and that B has a fixed probability of occurrence per time unit (=NB/T) throughout the continuous *observation period* (where NB is the number of occurrences of B and T is the duration of the observation period). d) If such a critical interval relationship is found, a simple pattern (AB) is defined - it occurs wherever an occurrence of A is followed by an occurrence of B within the critical interval. e) Real data, of course, typically contain many more *event types*. Thus, in addition to the pattern (AB) being detected, others may also be found (for example, (CD)). All occurrences of these simple patterns become events themselves, and are then added to the data and treated like the initial types of events in the next level of pattern detection.

THEME repeats the procedure above, level by level, searching for critical interval relationships involving the detected patterns. A critical interval relationship may thus be found between pattern AB and event type K, giving rise to the pattern ((AB)K), or between the simple patterns (AB) and (CD), producing the more complex pattern ((AB)(CD)). These may then become parts of still more complex patterns.

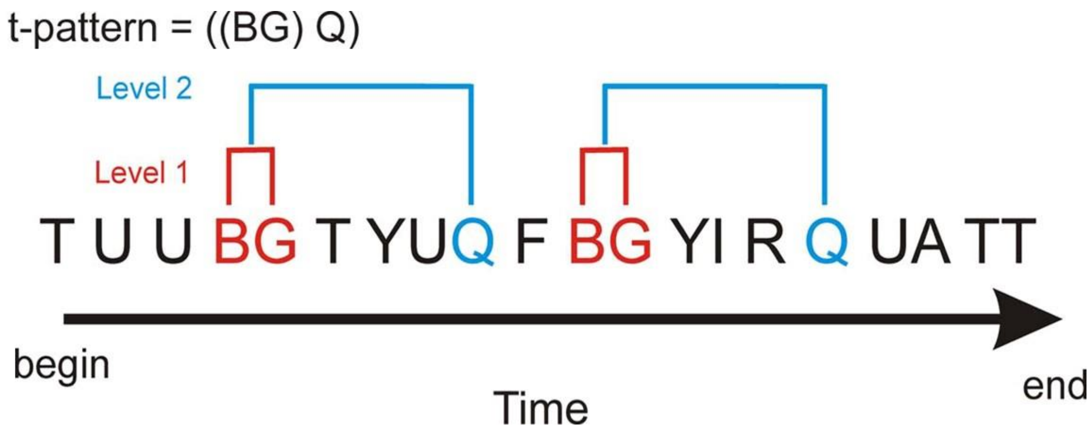

Figure 2. T-pattern detection process.

This iterative process continues until THEME has considered all possible combinations of all event types and searched for patterns at all levels. Throughout this process, patterns thus grow in complexity but some may simply be partial detections of more complex patterns, with one or more elements missing. Such incomplete patterns do not survive and are deleted. By employing this evolutionary approach to pattern detection, THEME produces the most complete patterns possible - and therefore typically the most interesting ones.

The result of THEME analysis process, as it stands, does not infer that events within a pattern are causally related. The detection algorithm is neutral to this issue, which concerns the interpretation of detected patterns. In other words, we cannot assume that, just because a pattern exists, the elements within it are causally related. Discovering the meaning of the patterns and the events within the patterns is something that only concerns the researcher.

This kind of analysis has been used in a wide variety of observational studies, including microanalysis of Drosophila courtship behavior (Arthur & Magnusson, 2005), cooperative behavior between humans and dogs when constructing an object (Kerepesi et al., 2005), patient-therapist communication in computer assisted environments (Riva, Zurloni, & Anolli, 2005), and in the field of sport, such as analysis of soccer team play (Camerino, Chaverri, Anguera, & Jonsson, 2012), motor skill responses in body movement and dance (Castañer, Torrents, Anguera, Dinušová, & Jonsson, 2009), effectiveness of offensive plays in basketball (Fernandez, Camerino, Anguera, & Jonsson, 2009).

One reason for focusing on this pattern type is its widespread occurrence in various kinds of behavioral streams and at highly different time scales, suggesting its importance in the organization of behavior. A further reason is that these patterns easily become invisible to the naked eye when other behavior occurs in parallel with them. Moreover, patterns of this kind may often be hard or impossible to detect with the well-known statistical methods that are found in major statistical program packages and behavior research software, such as The Observer (Noldus, 1991; Noldus, Trienes, Hendriksen, Jansen, & Jansen, 2000) or GSEQ (Bakeman & Quera, 1995).

Discovering the real-time multi-layered and parallel structure of even the most common dyadic verbal and nonverbal interactions represents a formidable challenge where clues to deception may be hidden to unaided observers in anything from the tiniest of details to intricate aspects of temporal structure. We think that T-pattern sequential analysis may be a particularly suitable tool for defining and discovering repeated temporal patterns in deceptive behavior.

This approach might help overcoming on one hand, the inability of human beings as lie detectors, on the other hand, their ability as liars, by revealing hidden and unknown structures also to who puts them to use. One objective of this work, thence, is proving the efficacy of t-pattern analysis and THEME in the field of deception detection too, taking into account that this research area is nearly unexplored, although in our opinion, it could bring useful results to a domain where potential applications are many and of great importance, first among them, people's security.

PART III:
EXPERIMENTAL STUDIES

CHAPTER 6: PILOT STUDY

In the previous chapter, we discussed our methodological approach, based on the combination of three large factors.

While cognitive load manipulation and multimodality are already known in literature and were applied to deception detection, the novelty in the proposed analysis methodology (t-pattern) has required a pilot preliminary study.

6.1 OBJECTIVES

- Evaluating the goodness of the coding grid for a t-pattern analysis;
- Verifying the suitability of the reverse mode as a technique for manipulating cognitive load within a t-pattern detection approach;
- Finding differences between lie and truth-related patterns that allow to express specific hypotheses on these patterns' distinctive.

6.2 METHODOLOGY SUMMARY

Cognitive load manipulation

We chose to use reverse mode, the most acknowledged and widespread in literature (cf. pag. 41) and more fit to the kind of task requested of our subjects (report an autobiographic episode), with the aim of verifying its efficacy in a t-pattern approach.

Multimodality

Since the literature review does not identify univocally a "Pinocchio's nose" and the novelty of the t-pattern approach, we decided to consider a wide range of nonverbal behaviors, with the aim of defining an ideal coding grid for this kind of analysis methodology.

T-pattern analysis

The datasets will be analyzed with THEME 6 Beta (Magnusson, 2000; 2004; 2005).

6.3 HYPOTHESES

According to the literature review, we formulated the following hypotheses:

H1: there are differences between patterns detected in liars and patterns detected in truth tellers.

H2: the differences in patterns between liars and truth tellers should be more evident in the experimental group, compared to the control one.

6.4 METHOD

This pilot study was carried at the University of Milano-Bicocca in an audio-isolated laboratory room equipped with four cameras, set to video-record participants' full-lengths and close-ups. The cameras were connected to a 2-channel quad device (split-screen technique).

Participants

16 students, all females, aged from 21 to 26 (mean age 23.45 ± 2.13), all native to the same geographic area. They were recruited at the faculty of Psychology from the University of Milano-Bicocca. After being recruited, all participants gave their informed consent both to audio and video recording.

Procedure

We asked participants to think about two autobiographical episodes. One of the stories had to be about the last time they went out to have a pizza with friends (which happens quite often in Italy); the other had to be about their last night out for a party. We selected these kind of arguments trying to maintain the arousal and the emotional involvement as low as possible. For the same reason we asked participants to focus on the descriptions of events rather than the emotional or affective aspects of the stories. Finally, subjects who didn't follow these indications were excluded from further analysis.

Participants were given 20 minutes to prepare the two stories, knowing that after they would have to report both episodes to another person (a confederate), keeping in mind that one of these two episodes had to be untruthful and that the interlocutor didn't know which one. We asked half of the students to tell the pizza episode first, while the other half did the opposite. All of them were told to lie during the first episode.

We controlled motivation by telling them that, if they succeeded in telling the lie (meaning, the confederate couldn't tell which episode was made up), they would receive extra credits.

In the first experimental condition, the confederate asked the participant to report both episodes in chronological order. For future reference, we will refer to this condition as the Normal condition (no cognitive load manipulation). In the second condition, the confederate asked to report both episodes in reverse mode (starting from the end of the story and going back to the beginning). We will refer to this condition as the Reverse one. The time frame for the experimental task was 10 minutes for each participant (5 minutes per episode), marked by audio signals.

To establish the ground truth and verify cognitive load manipulation, motivation, arousal and emotional involvement, we asked the subjects to complete a questionnaire after the experiment was finished. Later, we watched the video recordings with the participants and asked them when they had lied (veracity status).

6.5 DATA ANALYSIS

The coding grid was built basing on literature review of nonverbal cues in lie detection (DePaulo et al., 2003) (Vrij, 2008), (Burgoon, Guerrero, & Floyd, 2010). We considered body movements (head, trunk, hands, legs and feet), gestures (rhythmic, iconic, metaphoric, symbolic/emblematic and deictic), self-contacts, gaze and some facial micro-movements (action units from FACS- Facial Action Coding System) (Ekman & Friesen, 1978).

Two-minute observation intervals were considered for subsequent analysis. Videos were coded on THEME coder software by two coders (both females, in accordance to the gender of the subjects) using a "blind" coding procedure. The occurrences of each event-type within the selected observation period form the so called "T-dataset".

To assess inter-rater reliability of the T-dataset, Cohen's Kappa was calculated on 10% of the encodings. Although differing through categories, inter-coder reliability was found to be good to satisfactory (ranging from 0.70 to 0.92; $p < 0.05$). When disagreements were identified or the agreement was not perfect, the specific cases were discussed and agreed by both coders.

Datasets were then analyzed using THEME 6 beta software (Magnusson, 2000; 2004; 2005).

FACE	au1	**HANDS**	handswithoutarms	**TRUNK**	trforward
	au2		fingerswithouthands		trlateral
	au4		emblemgest		
	au5		iconicgest	**LEGS**	legsmove
	au6		metaphoricgest		
	au12		deicticgest	**FEET**	feetmove
	au14		rhythmicgest		
	au17				
	au20				
	au23	**SELF_CONTACT**	objectfidgeting		
	au24		selffidgeting		
	au25		headfidgeting		
	au28		objectcontact		
	au41		selfcontact		
	au43		headcontact		
	au45				
		GAZE	gazetointerlocutor		
HEAD	nodding				
	shaking				

Table 1. The FACE category only contains action units (Ekman & Friesen, 1978). HEAD includes nodding and shaking. HANDS contains hand, finger movements, symbolic (emblemgest), iconic, metaphoric, deictic and rhythmic gestures. SELF_CONTACT includes codes that differentiate between object, self and head. Both contact and fidgeting are distinguished. GAZE only includes its direction to the interlocutor. TRUNK contains posture changes, forward or lateral. LEGS and FEET are coded when moving.

For our analysis, we created 2 THEME project files, one for each level of the cognitive load manipulation variable (the first project containing all datasets obtained in the Normal condition, the second containing all datasets obtained in the Reverse condition). We did this in order to compare truth and lie-related patterns between the normal and reverse condition. This had to be done necessarily in 2 different projects, since THEME can only merge datasets according to one independent variable at a time.

In each project, we combined datasets into 2 samples through the function Concatenate by Independent Variable. This function allows merging single datasets according to their independent variable status, while keeping information about each single dataset, so that it is possible to distinguish between single subjects even after the merge. We merged the samples according to the TRUTH/LIE condition. This gave us a NORMAL project in which we had two datasets (one consisting of the TRUTH merge and one for the LIE), and a REVERSE one, containing the related TRUTH/LIE datasets. This was done so that, within each cognitive load manipulation condition, we could analyze the differences between lie and truth-related patterns.

By means of relevant options, the program allows the experimenter to set specific search parameters. These parameters include a significance level, which is the maximum accepted probability of any critical interval relationship to occur by chance alone (cit. manual). This parameter specifies a threshold value, determining how far from random expectation critical interval relationships can occur for patterns to be kept or dropped. The smaller the value set, the less likely it is that patterns can occur at random; a minimum occurrences value can be set, defining the minimum number of times a pattern must occur to be detected; a minimum percentage of samples can be set, defining the minimum percentage of samples in which a pattern must occur to be detected.

Our settings were: significance level (.01), minimum occurrences (3) and minimum % of samples (80%).

6.6 RESULTS

COGNITIVE LOAD	VERACITY STATUS	PATDIFF	PATOCCS	LEN_MEAN	LEV_MEAN
NORMAL	TRUTH	98	1074	3,78	2,24
NORMAL	LIE	22	712	2,14	1,14
REVERSE	TRUTH	11	753	2,09	1,09
REVERSE	LIE	4	231	2	1

Table 2. PATDIFF: number of different t-patterns found; PATOCCS: total number of pattern occurrences; LEN_MEAN: mean of pattern lengths; LEV_MEAN: mean of pattern levels; ET_TOTAL: total number of event-types coded.

We chose to consider the most complex T-patterns, since they are regarded as the most interesting, due to their potential meaning and the (low) likeliness to be detected using other definitions and algorithms (Magnusson, 2000; 2004; 2005). However, we did not ignore less complex ones (e.g. those composed by only two event-types), but we considered the ones composed by event-types that are consistent with literature on lie detection, or able to explain more about the behavior organizations we explored.

Table 2 shows the number of different patterns found, the number of total pattern occurrences per sample, the mean for patterns' levels and lengths.

For each sample, we will specify the number of patterns found and the number of complex patterns among the found ones. By complex patterns, we mean the ones which include a combination of at least three event-types (adding information as to the general complexity found in the samples' patterns).

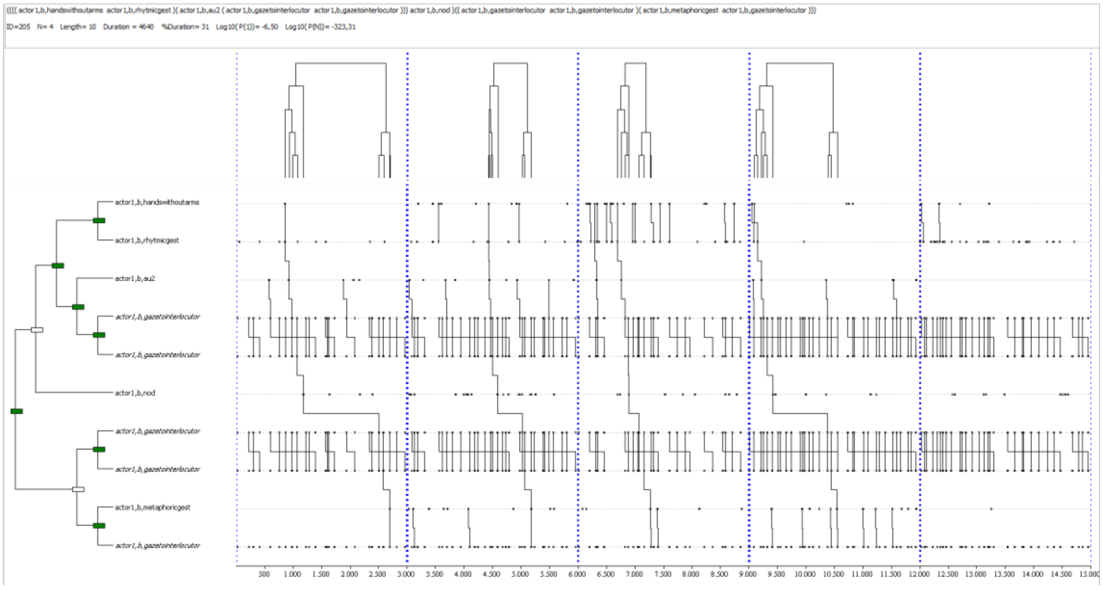

Figure 3. This pattern has 5 levels and a length of 10 event-types. It begins with a hand movement, followed by a rhythmic gesture, au 2, gaze contact (twice), a nod, two gaze contacts again, a metaphoric gesture, and ends with a gaze contact. It is distributed among 4 out of 5 samples.

Within the normal condition, the truth sample contained 98 patterns, of which 62 contain a combination of at least three event-types (63%). The most complex include combinations of gaze-contact and au45, combined with rhythmic, metaphoric and iconic gestures, hand gestures, nodding and head shaking, and au2 (see Figures 3 and 4 for an example).

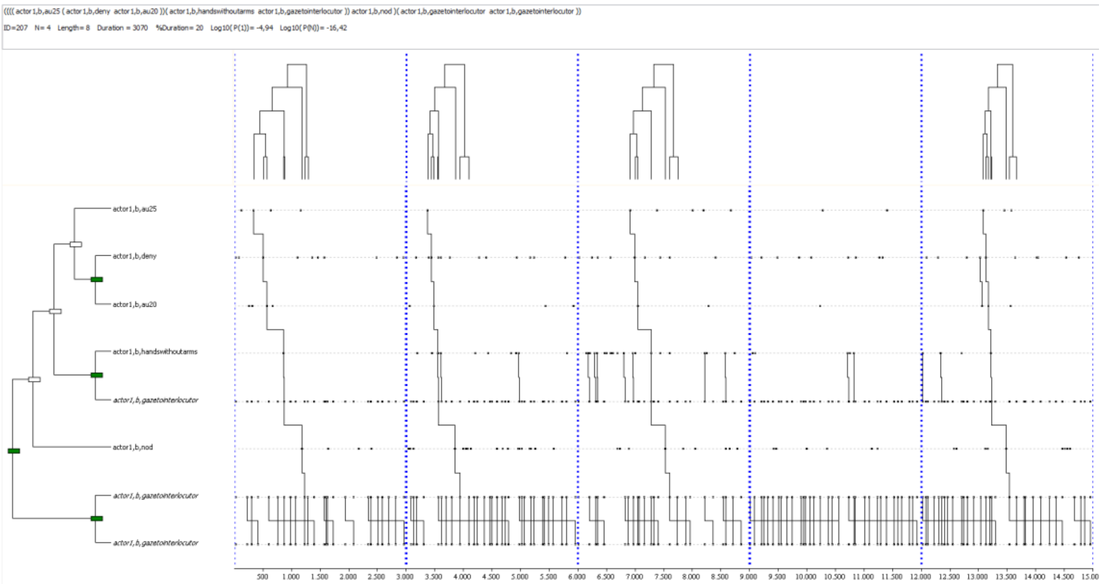

Figure 4. This pattern has 5 levels and a length of 8 event-types. It begins with au25, followed by head shaking, au20, a hand movement, gaze contact, nodding, and gaze contact (twice). It is distributed among 4 out of 5 samples.

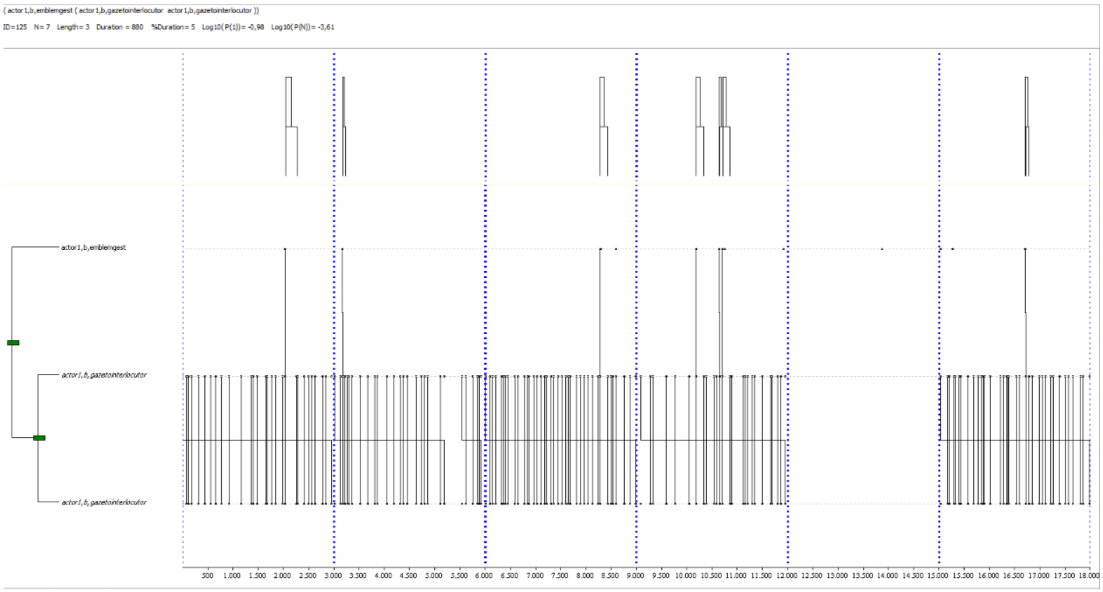

Figure 5. This pattern has 2 levels and a length of 3 event-types. It begins with an emblematic gesture, followed by two gaze contacts (gazetointerlocutor). It is distributed among 5 out of 6 samples.

In the lie sample, out of 22 patterns, only 3 meet the requirement to be considered complex (13.6%). These contain gaze-au45 combinations, emblematic gestures, head shakes, au6 and au12 (which are found together in one pattern, probably indicating truthful smile, and appear separately on different patterns. The au12 could be an indicator of a fake smile. We'll discuss this in the next paragraph; see Figures 5 and 6 for an example).

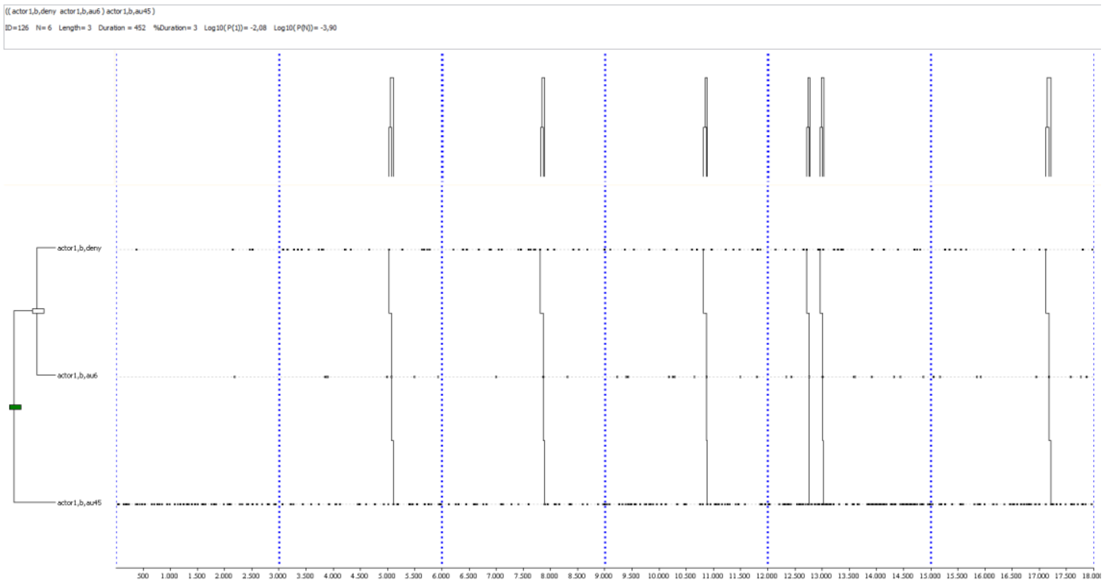

Figure 6. This pattern has 2 levels and a length of 3 event-types. It begins with head shaking (deny), continues with au6, and ends with blinking (au45). It is distributed among 5 out of 6 samples.

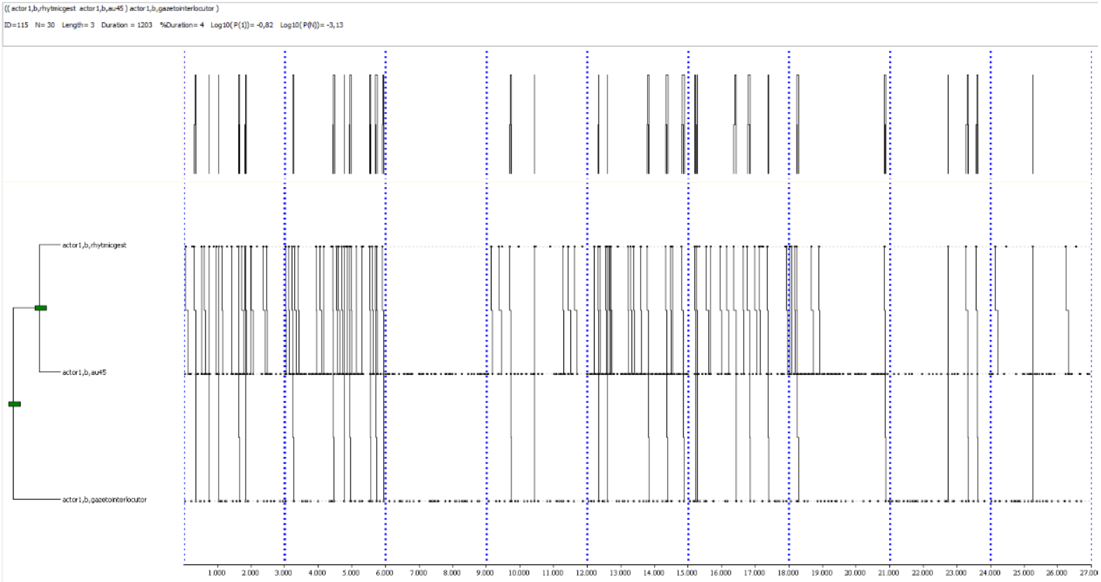

Figure 7. This pattern has 2 levels and a length of 3 event-types. It begins with a rhythmic gesture, followed by blinking and gaze contact.

Within the reverse condition, in the truth sample, out of 11 patterns found, only one is basic-complex (9%); it contains a combination of rhythmic gestures and gaze-au45 combinations (see Figure 7).

In the lie sample, only 4 patterns were found, none of them containing more than a combination of two event-types (see Figure 8). The event-types included in these patterns contain au45-gaze combinations and head shakes, along with rhythmic gestures.

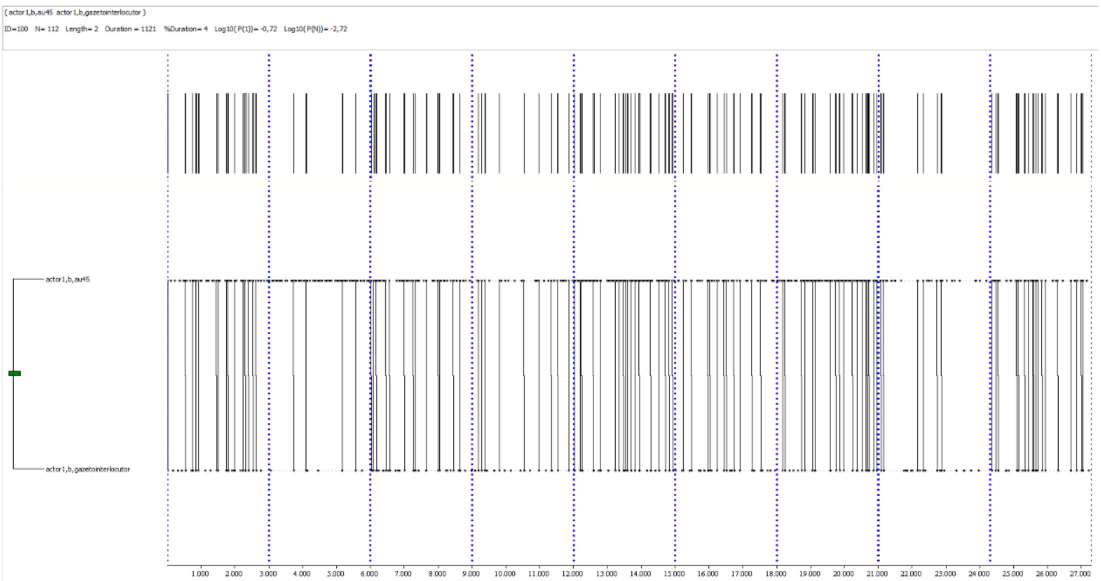

Figure 8. This pattern has 1 level and a length of 2 event-types. These are just a combination of blinking (au45) and gaze contact. It is distributed among all samples.

6.7 DISCUSSION

T-pattern analysis is a relatively young methodology, and this work represents one of the first attempts to apply it to deception detection. The results of the pilot study will now be discussed in relation to the literature, keeping in mind that talking about behavioral patterns and single cues are two very different things, and that, at the moment, there is no literature concerning t-patterns of human behaviors in truth telling and lying.

First, we consider the quantitative data showed in Table 2. Generally, we can say that the normal condition is characterized by a larger variety and a number of patterns than the reverse condition (see Figures 9 and 10). This could mean that, in conditions of no manipulations to the cognitive load, nonverbal behavior seems to be more varied and organized, showing a greater richness and harmony.

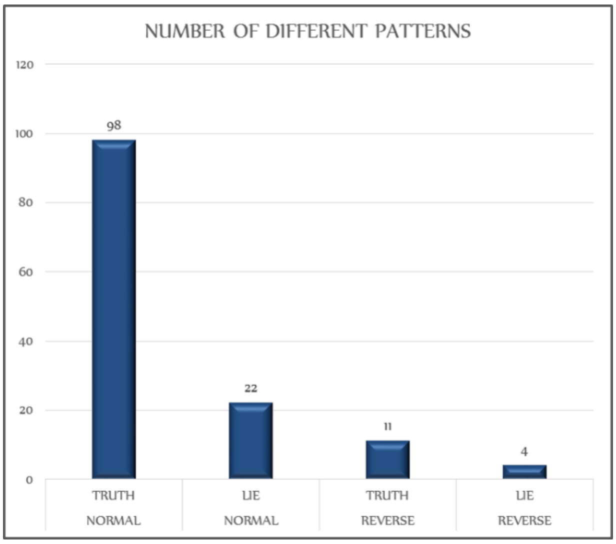

Figure 9. Number of different patterns.

The reverse condition, on the contrary, is characterized by a definite minority in number and variety of patterns, possibly meaning a flattening effect and an impoverishment of behavior, related to a high cognitive load.

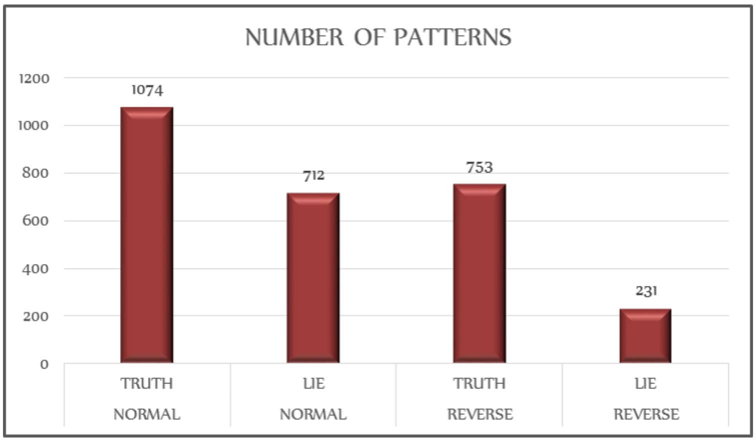

Figure 10. Number of patterns.

The same things can be said about length and levels of patterns that, overall, give us information about the complexity of the pattern itself (see Figure 11). We can see how, in the normal condition, patterns are generally more complex than in the reverse condition, which could suggest that a cognitive overload produces a simplification and decrease of the behavior organization.

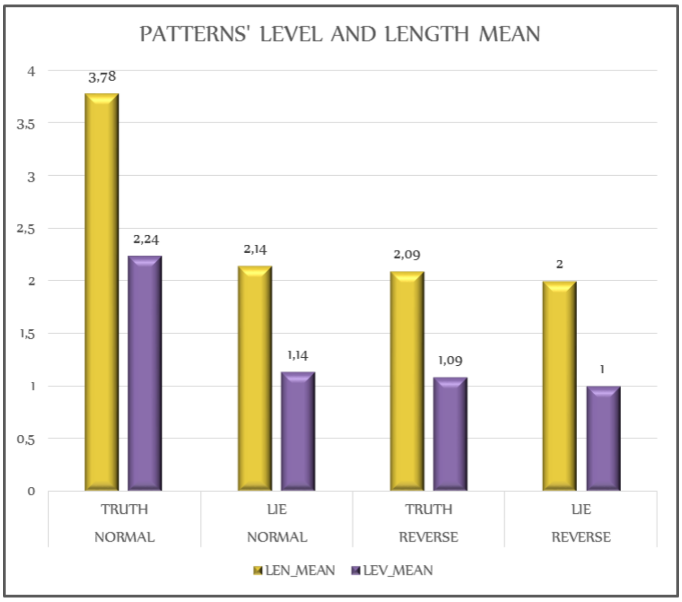

Figure 11. Patterns' level and length mean.

These two conditions, however, present clearly different conditions within. In the normal condition, truth is characterized by a greater number and variety of patterns than lie. These patterns, moreover, are longer and made of more levels (more complex). We think that this difference could depend on the higher cognitive load that characterizes lying compared to truth, as already pointed out by different authors, and especially Vrij (2008). The reverse condition, to the contrary, presents minor quantitative differences in variety, length and levels of patterns. To be noted, instead, is how the total number of pattern changes, considerably higher in truth-telling than in lying. Therefore, behavior seems to be generally simple and stereotyped, but more organized in truth-telling.

Now we consider qualitative differences, i.e. the behaviors that form different patterns.

In the normal condition, truth is characterized by considerably complex patterns that involve many different behaviors. This level of richness and complexity make it hard to interpret and assign meaning to the patterns found; what we can say is that, in patterns, there are different illustrators (metaphoric and iconic gestures) which, as pointed out by other research (Vrij et al., 1997), characterize sincere accounts. There are also head movements (nodding and shaking) and blinking patterns.

Lie-related patterns are much simpler and involve fewer behaviors. We found symbolic gestures (not tied to the context), and more importantly, nodding (Sporer & Schwandt, 2007) disappears from patterns. Au6 and au12 (which, combined, represent sincere smile) appear separately in patterns related to lie. This result could indicate that, in order to reveal this behavior (for which the synchrony between the two indicators is essential), it would be better to create a specific category in the coding grid which contains both of them in one behavior and another category only composed by the au12.

As for the reverse condition, the situation is quite different. A difference between lie and truth is still there, and it follows the trend highlighted in the normal condition group, but it is significantly decreased. Both lie and truth are characterized by a repetition of simple patterns and, in the case of lie patterns, too simple to assign meaning to. The only cue seems to be head shaking, which only appears in lie patterns. However, we do not have sufficient data to draw conclusions in a direction or the other.

Summing up, these results show how there are differences in behavioral patterns between truth and lie, certainly in terms of number, variety and complexity. The first hypothesis, therefore, is supported.

Increasing the cognitive load can be useful because, reducing all parameters, it could make identifying distinctive characteristics and attribution of meaning easier (much harder, for example, in a situation such as the control group's truth patterns). The reverse condition, however, doesn't seem to be the most efficient technique for this kind of analysis, since it created a floor effect on all variables considered, canceling most part of the differences between truth and lie and making the results so poor that they become almost useless. We hypothesize that the reverse task is cognitively too hard, even when telling the truth, especially if motivation is medium-low (we don't expect our participants to have the same motivation for not being unmasked if something more than some extra credits was at stake). For these reasons, we reject the second hypothesis and attribute the inadequate differences between the two groups to the inappropriateness of the reverse mode as a method to manipulate cognitive load in participants with a medium-low motivation and within a t-pattern approach.

Furthermore, we believe the coding grid was too complex with respect to the length of the observation period. It has increased the difficulty of the results' interpretation, already high because included in a new methodology and with almost no theoretical background on the specific matter.

6.8 CONCLUSIONS

The objectives of this study were three. We'll now discuss if and how each of them has been reached. As for the first objective, our results suggest that the coding grid we used was too complex; the solutions could be a simplification of the grid, or an increase in observation time length. As for the second objective, our data highlighted how reverse mode is not the fittest cognitive load manipulation technique for the study of deception in conditions of medium-low motivation and within a t-pattern approach. As for the third objective, we can generally take indications about number, variety, and complexity of patterns, with reserves concerning the limitations of the study, which we will discuss later. We are not able, instead, to formulate hypotheses on which behaviors might compose truth and lie-related patterns.

Although the data of the current research lends some support to our objectives and general line of argument, we will now talk about limits. First, as we asked participants to tell the truth or lying about their autobiographical episodes, it is critical to address the question of whether we can entirely consider these self-reported episodes truthful (Kaplar & Gordon, 2004). Self-report measures of deception are commonly used (Ennis, Vrij, & Chance, 2008), but often questioned based on response biases and individuals' awareness of how frequently they lie. For instance, lie tellers may give socially desirable versions of their autobiographical episodes violating the experimental instructions (Paulhus, 2002). To reduce such uncertainty, before the experimental phase we had an extensive initial briefing session with the participants in which we emphasized the importance of accuracy and conscientiousness. Moreover, after the recording of the autobiographical episodes we asked participants to tell us if they accurately followed the experimental instructions.

Given our main objectives, we took a convenience sample. Since the departments we turned to in order to recruit participants were mainly composed of females, we found it quicker to use a heterogeneous female sample, for immediate temporal reasons related to the pilot study, because counterbalancing it would have inevitably taken much longer times.

We deliberately confined our studies to women whose age ranged between 21 and 26, but this methodology should be applied for studying deception detection to wider samples in terms of age range and gender.

CHAPTER 7: SECOND STUDY

This chapter presents the results from our second experimental investigation. They will be discussed according to literature and results of the pilot study.

7.1 OBJECTIVES

- Verifying the presence of significant and systematic differences in nonverbal behavior patterns between lying and truth telling
- Finding differences in cues of disfluency between lie and truth
- Evaluating the suitability of the memory task for sentences, as secondary task in a dual-task procedure, as a technique for manipulating cognitive load within a t-pattern detection approach;
- Demonstrate the effectiveness of the T-Pattern approach in lie detection.

7.2 METHODOLOGY SUMMARY

Cognitive load manipulation

Based on the pilot study's results, we decided to use a different technique to manipulate cognitive load, attempting to act on the extraneous load (cf. pag. 40). Specifically, we decided to use a dual-task procedure, and having as a secondary task a memory task for sentences. The choice of this task in particular depended on two factors: the first is related to the objective of this research work, i.e. the observation and analysis of behavioral patterns. In fact, we had to exclude any task that gave limitations to our participants in terms of movements, gaze direction and verbal expression (e.g. the repetition of numbers or pen and paper paths). The second factor is related to the kind of primary task required, that is give a detailed account or lie about facts showed in a video. We believe, indeed, that the memorization task, if administered and carried out after preparing the report related to the main task, would interfere with the cognitive processes involved in the processing of the report itself, and especially with its consolidation in memory. The sentences, identical in number of words and syntactical structure, contain elements that are also present in the video, clearly in a different context (e.g. "two friends smoke a cigarette at the park", there are two men in the video who smoke a cigarette while watching football). We tried to create this partial overlapping to increase interference during the processing of the account.

Multimodality

Following the indications emerged from the pilot study, we decided to modify and simplify the coding grid. For this reason, we only took in consideration the Action Units related to significant cues in literature, and created a unique code for authentic smile (au6 + au12, cf. pag. 30); we grouped all illustrator gestures in one category, we did the same for adaptor gestures, and trunk movements were merged in a general category including all posture shifts. We also decided to take disfluency cues in consideration. Speech transcriptions have been analyzed with NOOJ software (Elia et al., 2010; Silbertzein, 1993, 2007; Vietri, 2008). .

T-pattern analysis

The datasets were analyzed with THEME 6 XE3 software (Magnusson, 2000; 2004; 2005). The updated version of this software allows for new kinds of analyses, for example comparison between real data and randomized data, which permits to verify the validity of results.

7.3 HYPOTHESES

According to the literature review and the findings of the pilot study, we formulated the following hypotheses:

H1: T-patterns number, variety and complexity decrease in liars.

H2: The differences in patterns between liars and truth tellers increase in the experimental group, compared to the control one.

H3: Disfluency cues are more present in the lie condition than in the truth one.

H4: Disfluency cues increase in the experimental condition when compared to the control one.

7.4 METHOD

The current study was carried at the same laboratory that was used in the pilot study.

Participants

The sample was composed by 40 students, (half of them are male, half are female), aged from 21 to 31, mostly native to the same geographic area. They were recruited through the University's online study recruiting platform. What they know is that they will participate in an experiment concerning their communicative abilities related to working memory, with no mention of deception. At the beginning of the experiment, all participants signed an informed consent both to audio and video recording. Each participant received a 5 euro reward. To increase motivation further, they have the guarantee of a restitution of the results, so they will get access to information about their communicative skills.

Instruments and materials

In this experiment we use:

- The State-Trait Anxiety Inventory (STAI), a psychological inventory based on a 4-point Likert scale which consists of 40 questions on a self-report basis. We used it to measure trait and state anxiety.
- Memory span test, where a list of random sets of numbers is read out loud at the rate of one per second. At the end of each set, the participant is asked to recall the items in order. After 3 correct recalls, a new battery of sets is presented, containing an extra number, and so on. A streak of 2 errors in the same battery determines the person's digit span.
- Corsi test for sequential spatial memory: it consists of a plastic tray, with 9 cubes attached to it, numbered on the side facing the experimenter. The participant's task is to touch the cubes in the same order as they were touched by the examiner, right after presentation. Much like the digit span, each battery recalled correctly leads to a new one, containing an extra cube. A streak of 2 errors in the same battery determines the person's span for spatial memory.
- A video that was made for the experiment, divided into two segments, which are showed separately (see procedure for information about the order of each administration). The whole video is a no-dialogue story about 4 characters organizing a bank robbery and committing it. The video is silent because we wanted to avoid giving the viewers characters' words and to let them have freedom in the interpretation and accounting of the story (no violent acts or emotional involving events are depicted, in order to avoid arousal interference). The video was cut approximately in half, so that each segment's length is more or less the same as the other and contains the same number of events.
- Dual task procedure: in the experimental condition, participants are asked in two occasions to memorize a series of 4 sentences (the two series are different), balanced to contain the same number of words and the same

syntactic structure. They are told to remember these sentences since they will be asked to recall them at any time during the experiment. This extra memory task was inserted to produce interference in visual-spatial memory.

- NOOJ software (Elia et al., 2010; Silbertzein, 1993, 2007; Vietri, 2008). NOOJ is a linguistic development environment, created by Max Silberztein, which includes large-coverage dictionaries and grammars (e.g. French, English, Italian, German, Spanish, Portuguese, Hungarian, Russian, Serbian, and Slovene) and parses corpora in real time. It contains tools to create and maintain large-coverage lexical resources, as well as morphological and syntactic grammars. Dictionaries and grammars are applied to texts in order to locate morphological, lexical and syntactic patterns and tag simple and compound words.

Procedure

The whole experiment lasts around 40-50 minutes. After signing the informed consent form, participants have to fill in a STAI_T inventory. After this, the experimenter administers them a digit span memory test and a Corsi test for spatial memory. These tests have been administered as post-hoc control for possible outliers (anxiety levels too high or cognitive capacities too distant from the average). Then, they are asked to watch a video (the first one) and pay attention to every detail, explaining them that the next part of the experiment will concern this particular video. They are left alone to watch the video.

As soon as they're done watching it, the examiner asks them to fill out a STAI_S inventory, in order to measure the state anxiety (and verify possible changes in arousal provoked by watching the video or other conditions).

Then, depending on the trial, they will be told they will have to report what they saw in the video to an interlocutor who hasn't watched it, or that they will have to lie about what they saw in the video to an interlocutor who hasn't watched it. In both cases, they are told to report/lie about the events and their details. The order of trials has been randomize to control the order effect, so half of the participants lie about the first video, while the other half lie about the second one. They are given a list of things they can use in their report (if they have to lie, there are examples of details that could be changed, such as the number or gender of the characters, their aspect, their actions, etc.). They are given 5 minutes alone to recall and organize their report (mentally).

The participants, males and females, were randomly assigned to two conditions.

In the experimental condition, a dual task procedure was carried out (cognitive load manipulation) so, when the time for preparing their report is up, participants are given a list of 4 numbered sentences to memorize and are told that they will have to recall them (when asked by the examiner) at random times during their report. They are given 2 extra minutes to memorize the sentences. They did not know when they would be interrupted or which sentence would have been asked to recall, nor did they know how many times they would have been interrupted. Because of this, the instructions for them specified to keep the sentences in mind and trying to do so through the whole report.

After this, an interlocutor is brought to the room and presented to the participant. After an audio signal, the participant will start to tell his/her report to the interlocutor, who does not participate in the conversation (this is the part we recorded).

After this part, the examiner goes back to the room and restarts the same routine with the second video (second part of the story). They are given the same instructions as before.

After watching it, the examiner asks them to fill in another STAI_S questionnaire, and then tells them (depending on what they had to do after watching the first video) to prepare to report or lie about the video to the interlocutor. In both cases, they are told the interlocutor doesn't know which part of their story is made up (but that he knows that one part is), so they don't have to worry about inconsistencies with their first report, since they are expected. After preparation, depending on the condition, they will be given a new list of 4 sentences to memorize and recall during their report.

Then, like before, the interlocutor is brought back to the room and, after an audio signal, the participants will have to start their report. At the end, the examiner tells them the experiment is over and answers any question they might have about the experiment.

For future reference, the condition where the cognitive load is manipulated will be referred to as the Experimental condition, while the condition with no manipulation will be referred to as the Control condition.

7.5 NONVERBAL VISUAL CUES

7.5.1 Data analysis

Four participants were eliminated from analysis; two of them were deleted for technical problems (for one of them the audio was not captured, while there was a problem with the camera in the other one, not allowing to see the face correctly), the other two didn't follow the instructions given. Therefore, the analyzed sample is taken from 36 participants.

The coding grid (see Table 3) was built basing on literature review of nonverbal cues in lie detection and evidence gathered from the pilot study (DePaulo et al., 2003; Vrij, 2008; Burgoon et al., 2010). We considered body movements (head, posture shifts, legs and feet), gestures (rhythmic, illustrator, symbolic and adaptors), gaze aversion and facial micro-movements (action units from FACS- Facial Action Coding System) (Ekman & Friesen, 1978).

GAZE	aversion	**GESTURES**	illustrator
			rhythmic
HEAD	nodding		symbolic
	shaking		adaptor
			fingers only
ACTION UNITS	au43		
	au45	**LEGS**	legmove
	au6_12		
	au12	**POSTURE**	posture shift

Table 3. The GAZE category only contains aversion. HEAD includes nodding and shaking. The ACTION UNITS are described in the FACS Manual (Ekman & Friesen, 1978). GESTURES contains illustrator, rhythmic, symbolic, adaptor and fingers only gestures. LEGS are for leg movements. POSTURE is for posture shifts of any kind.

Two-minute observation intervals were considered for subsequent analysis. The videos were coded on Behavior Coder software by two coders using a "blind" coding procedure. The occurrences of each event-type within the selected observation period form the so called "T-dataset".

To assess inter-rater reliability of the T-dataset, Cohen's Kappa was calculated on 10% of the encodings. Although differing through categories, inter-coder reliability was found to be good to satisfactory (ranging from 0.78 to 0.90; $p < 0.05$). When disagreements were identified or the agreement was not perfect, the specific cases were discussed and agreed by both coders.

Datasets were then analyzed using THEME 6 XE3 software (Magnusson, 2000; 2004; 2005).

We conducted two different analyses. The first analysis we carried out was similar to the one used for the pilot study. We created two THEME project files, one for each level of the cognitive load manipulation variable (a project containing all datasets from the CONTROL condition and one containing all datasets from the EXPERIMENTAL condition). We used the "Concatenate by Independent Variable" function to merge the datasets in each project according to their TRUTH/LIE status, obtaining two samples in each project (CONTROL project contained a sample including all control/truth datasets and a sample containing all control/lie datasets, while the EXPERIMENTAL project contained a sample including all experimental/truth datasets and a sample containing all experimental/lie datasets). This allowed us to compare truth-related patterns to lie-related patterns in the control condition and in the experimental condition. Because THEME only allows one independent variable to be used for merging datasets, we had to separate control and experimental datasets.

The second analysis was carried out to analyze gender-related differences in patterns. In this case, we created 4 different THEME project files. In each of these projects we used the usual Concatenate by Independent Variables function to obtain a lie sample and a truth one. Therefore, we had a project for Control/females, one for Control/males, one for Experimental/females and one for Experimental/males (each project contained two samples, lie and truth). This way, we could analyze differences between lie and truth-related patterns in males and females.

Our search parameters were significance level (.01), minimum occurrences (3) and minimum percentage of samples (80%).

7.5.2 Results

Table 4 shows the results of the pattern search in the first analysis.

COGNITIVE LOAD	VERACITY STATUS	PATDIFF	PATOCCS	LEN_MEAN	LEV_MEAN
CONTROL	TRUTH	41	5937	2,34	1,34
CONTROL	LIE	51	6247	2,65	1,61
EXPERIMENTAL	TRUTH	34	4897	2,29	1,26
EXPERIMENTAL	LIE	46	7079	2,37	1,33

Table 4. PATDIFF: number of different t-patterns found; PATOCCS: total number of pattern occurences; LEN_MEAN: mean of pattern lengths; LEV_MEAN: mean of pattern levels.

As for the pilot, we chose to consider the most complex T-patterns.

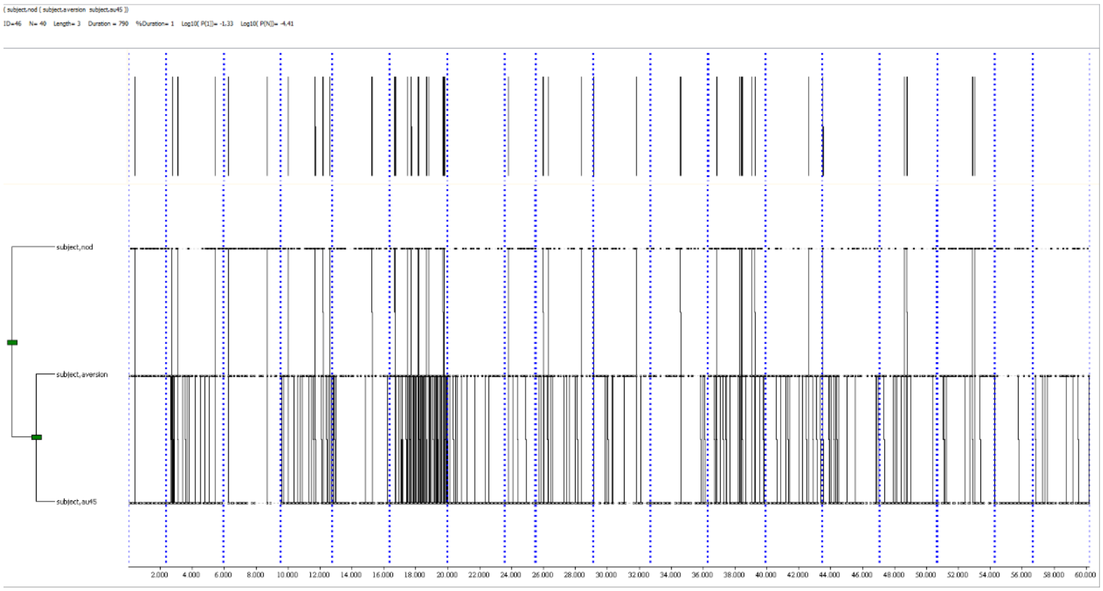

Figure 12. This pattern has 2 levels and a length of 3 event-types. It begins with nodding, followed by aversion and blinking. It is distributed among 15 out of 18 samples.

Within the control condition, the truth sample contained 41 patterns, of which 14 contain a combination of at least three event-types (34%). The most complex include combinations of gaze aversion and au45, followed by patterns combining head shaking and nodding movements. There are also many patterns containing gestures such as illustrator, rhythmic and adaptor gestures. The most complex pattern has a length of 3 event-types. See Figure 12 for an example.

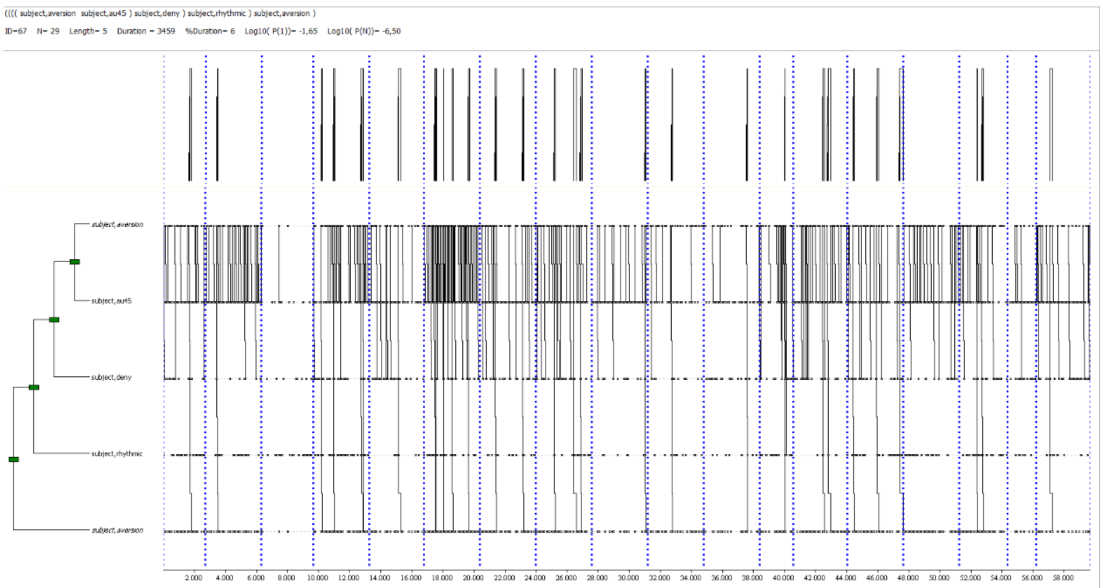

Figure 13. This pattern has 4 levels and a length of 5 event-types. It begins with aversion and blinking (au45), followed by head shaking, rhythmic gesture and aversion again. It is distributed among 15 out of 18 samples.

In the lie sample, out of 51 patterns, 23 meet the requirement to be considered complex (45%). These contain gaze-au45 combinations, along with head shaking, illustrator and rhythmic gestures. Within these complex patterns, more show presence of leg movements and posture shifts in patterns. The most complex pattern has a length of 5 event-types (see Figure 13).

Within the experimental condition, in the truth sample, out of 34 patterns found, 9 are complex (26%). The patterns detected include gaze-au45 combinations, followed by posture shifts and nodding movements (see Figure 14); they also include illustrator and adaptor gestures. The most complex pattern has a length of 5 event-types.

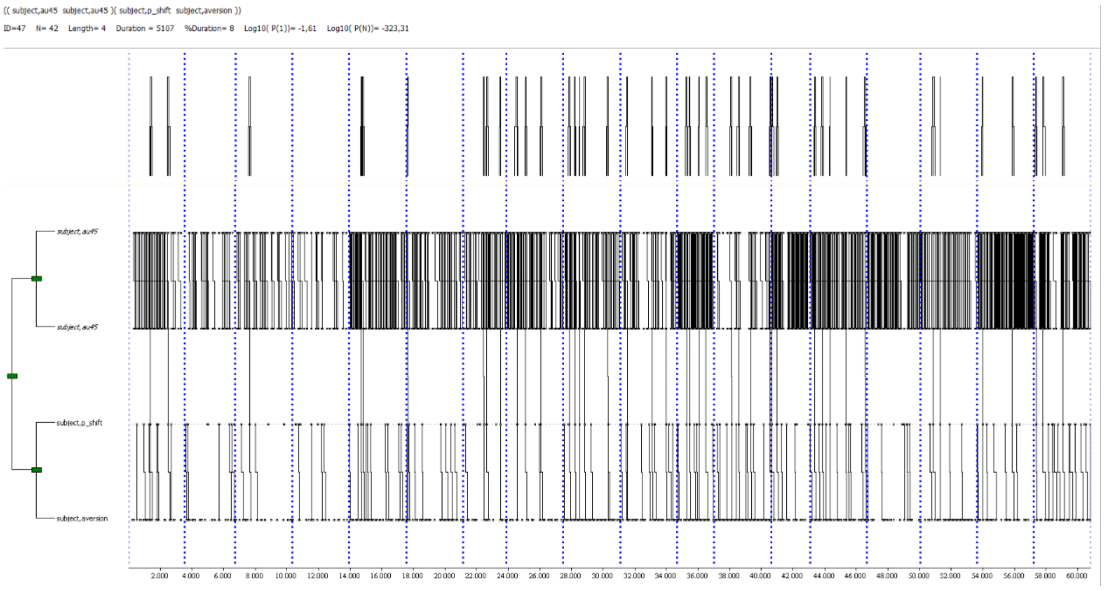

Figure 14. This pattern has 2 levels and a length of 4 event-types. It begins with blinking (twice, au45), continues with a posture shift and ends with aversion. It is distributed among 15 out of 18 samples.

In the lie sample, 46 patterns were found, of which 14 patterns are complex (30%). The event-types included in these patterns contain au45-gaze combinations and combinations of head shakes and nodding, followed by patterns including posture shifts and leg movements. Some patterns include gestures such as illustrator, rhythmic and adaptor. The most complex pattern has a length of 5 event-types (see Figure 15).

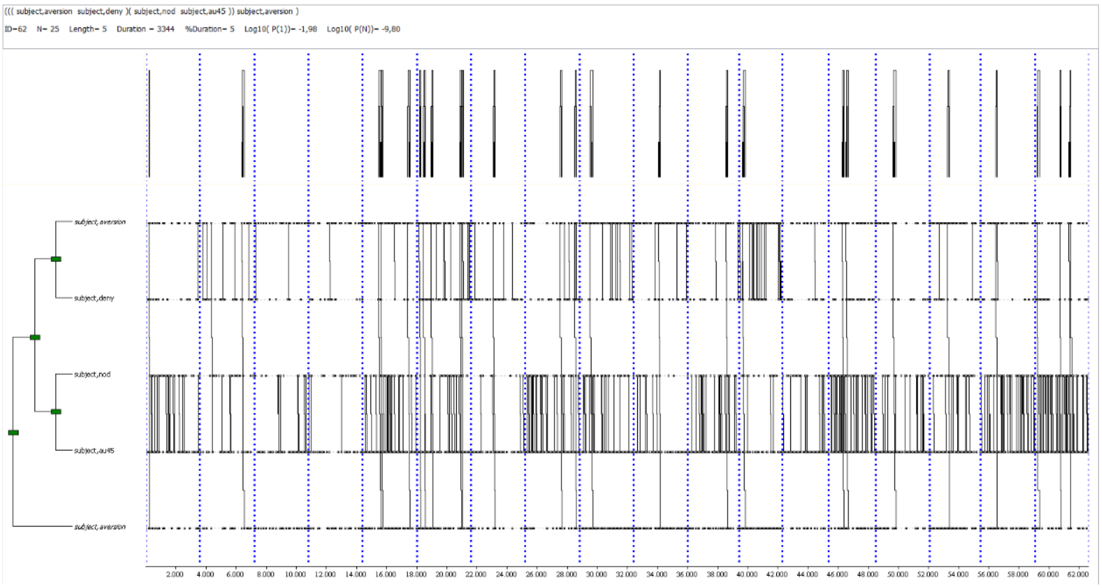

Figure 15. This pattern has 3 levels and a length of 5 event-types. It begins with aversion and head shaking, followed by nodding and blinking (au45), ending with aversion. It is distributed among 15 out of 18 samples.

Table 5 shows the results of the pattern search in the second analysis.

COGNITIVE LOAD	GENDER	VERACITY STATUS	PATDIFF	PATOCCS	LEN MEAN	LEV MEAN
CONTROL	MALE	TRUTH	39	2168	2,56	1,51
CONTROL	MALE	LIE	78	3338	3,19	1,9
CONTROL	FEMALE	TRUTH	80	4372	3,21	1,96
CONTROL	FEMALE	LIE	50	3198	2,92	1,8
EXPERIMENTAL	MALE	TRUTH	20	1439	2,2	1,2
EXPERIMENTAL	MALE	LIE	26	1854	2,27	1,23
EXPERIMENTAL	FEMALE	TRUTH	37	2712	2,59	1,51
EXPERIMENTAL	FEMALE	LIE	49	3423	2,76	1,71

Table 5. PATDIFF: number of different t-patterns found; PATOCCS: total number of pattern occurrences; LEN_MEAN: mean of pattern lengths; LEV_MEAN: mean of pattern levels.

Within the control condition, the males' truth sample contained 39 patterns, of which 17 contain a combination of at least three event-types (43%). The most complex include combinations of gaze aversion and au45 with nodding (see Figure 16), followed by patterns including illustrator gestures (also combined with nods), rhythmic gestures, leg movements and posture shifts, along with finger movements. The most complex pattern has a length of 4 event-types.

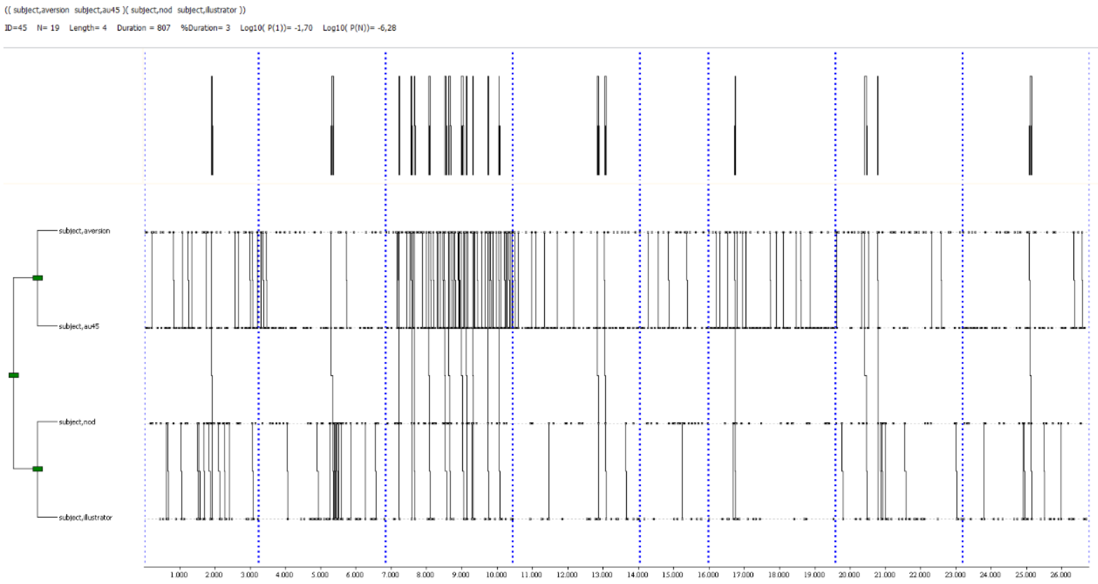

Figure 16. This pattern has 2 levels and a length of 4 event-types. It begins with aversion and blinking (au45), followed by nodding and an illustrator gesture. It is distributed among all samples.

In the males' lie sample, out of 78 patterns, 49 meet the requirement to be considered complex (62.8%). They mostly contain patterns combining illustrator and rhythmic gestures with gaze aversion behaviors (not au45 ones). Other patterns include head shaking (see Figure 17), finger movements, posture shifts and leg movements. The most complex pattern has a length of 7 event-types.

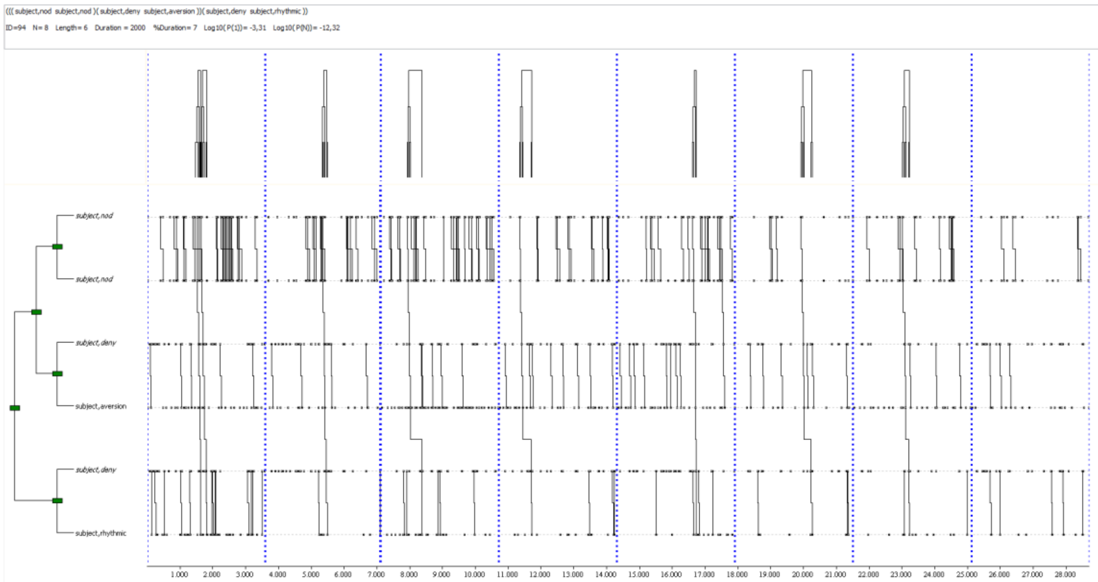

Figure 17. This pattern has 3 levels and a length of 6 event-types. It begins with nodding (twice), followed by a head shaking, aversion, head shaking again, and a rhythmic gesture. It is distributed among 7 out of 8 samples.

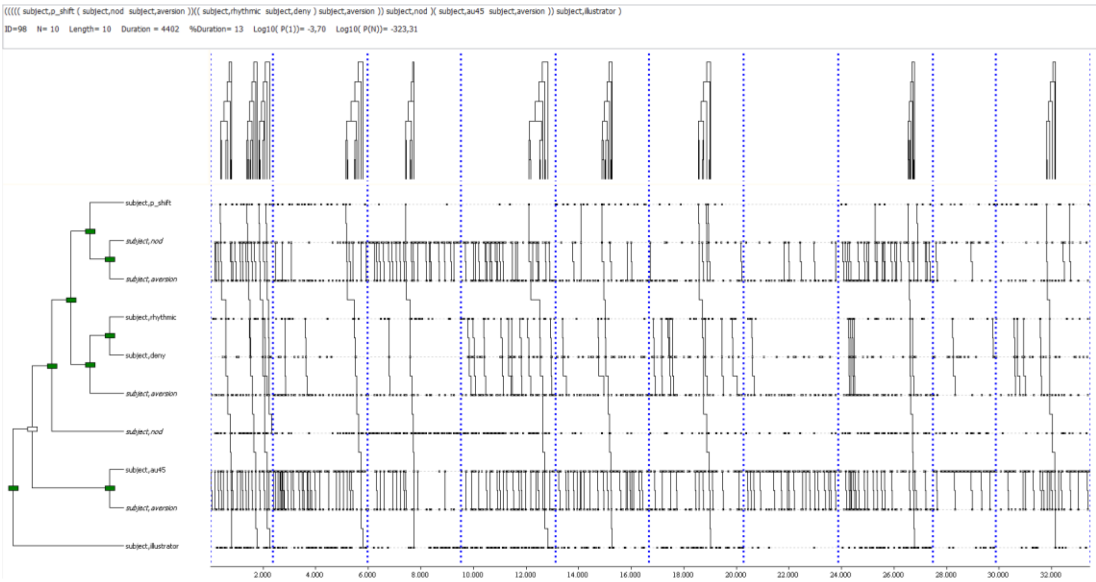

Figure 18. This pattern has 6 levels and a length of 10 event-types. It begins with a posture shift, followed by nodding, aversion, a rhythmic gesture, head shaking (deny), aversion again, nodding again, another combination of blinking and aversion, and it ends with an illustrator gesture. It is distributed among 8 out of 10 samples.

Within the females' truth samples, 80 patterns are detected, of which 51 are complex ones (63.75%). These include gaze-au45 combinations, nodding and shaking, illustrator and rhythmic gestures, symbolic gestures and feet movements. The most complex pattern has a length of 10 event-types (see Figure 18).

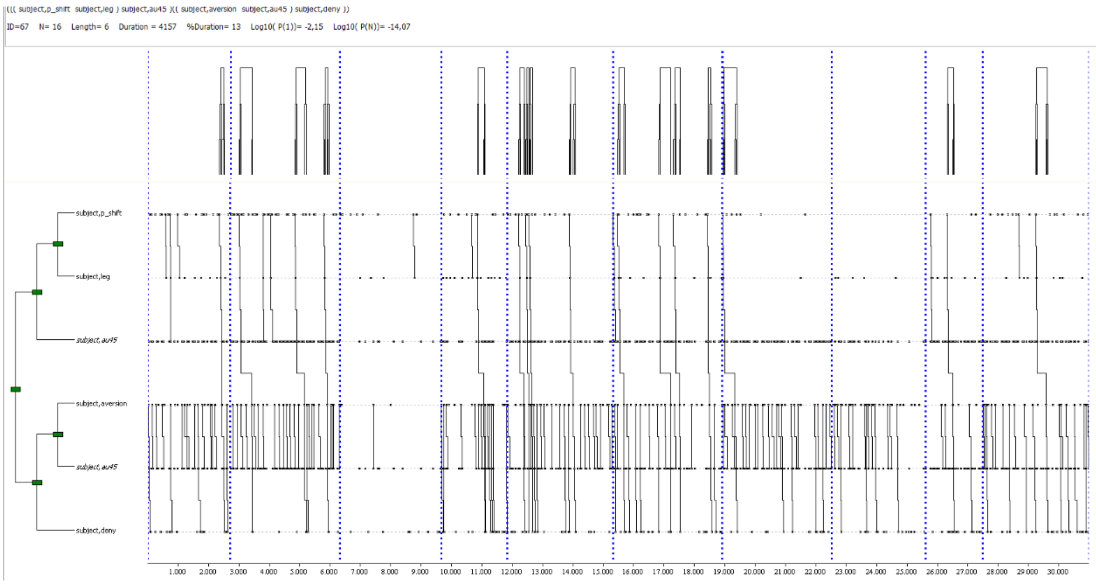

Figure 19. This pattern has 3 levels and a length of 6 event-types. It begins with a posture shift, followed by a leg movement; blinking (au45) comes after, followed by aversion, another blink, and it ends with head shaking (deny). It is distributed among 8 out of 10 samples.

The females' lie sample reveals 50 patterns, in which 28 are complex (56%). Among the detected patterns we find gaze-au45 combinations which include leg movements and posture shifts (see Figure 19), as well as head shaking, adaptor gestures and rhythmic gestures. The most complex pattern has a length of 6 event-types.

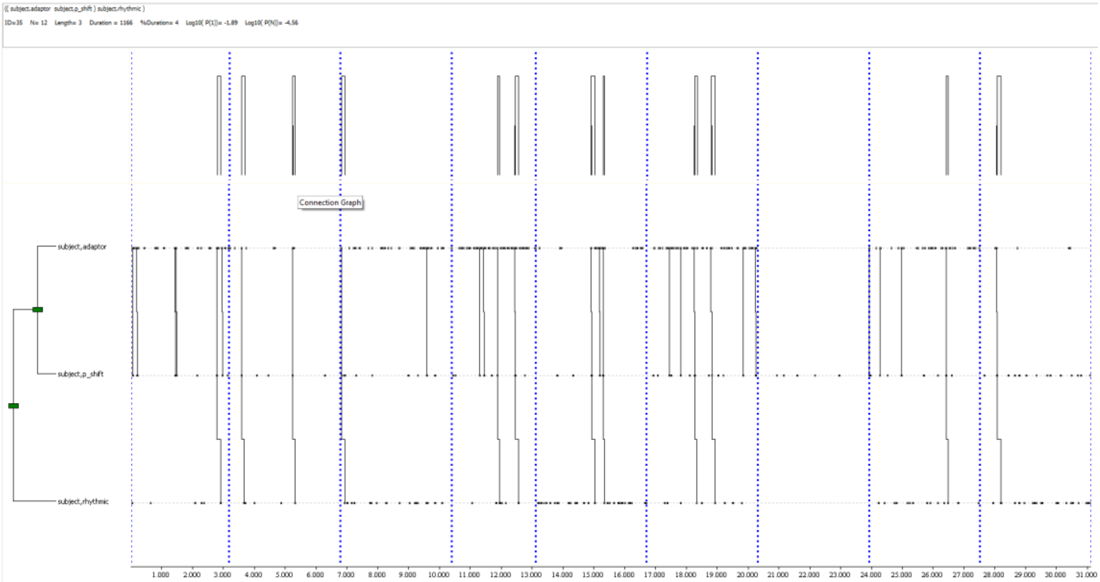

Figure 20. This pattern has 2 levels and a length of 3 event-types. It begins with an adaptor, followed by a posture shift and ending in a rhythmic gesture. It is distributed among 8 out of 9 samples.

Within the experimental condition, in the males' truth sample, 20 patterns are found and 4 of them are complex (20%). Few of the patterns detected include gaze-au45 combinations, while more included rhythmic and adaptor gestures, followed by posture shifts (see Figure 20). The most complex pattern has a length of 3 event-types.

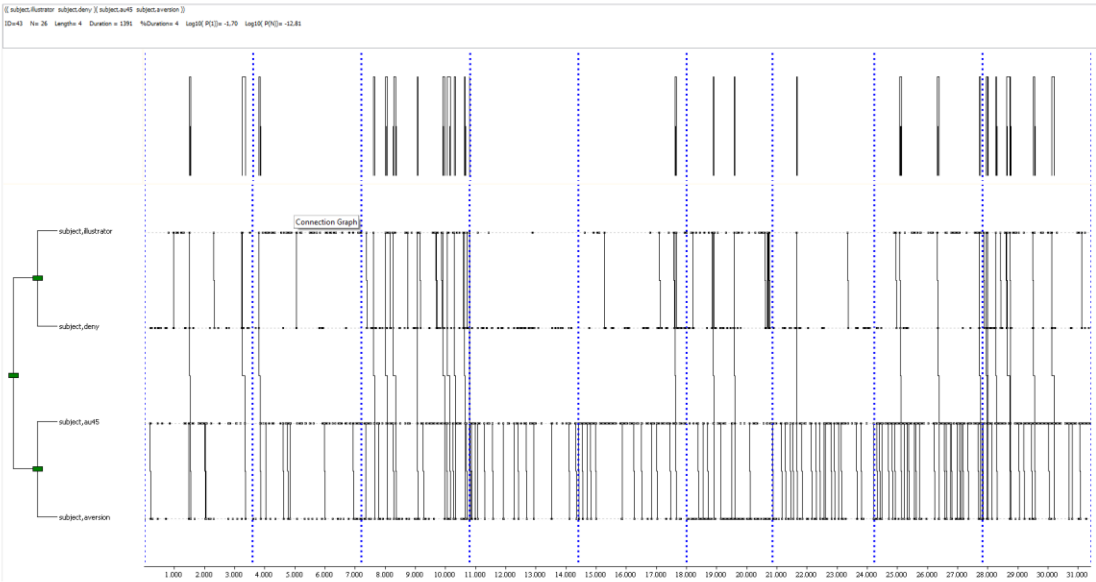

Figure 21. This pattern has 2 levels and a length of 4 event-types. It begins with an illustrator gesture, followed by head shaking, blinking (au45), and ends with aversion. It is distributed among 8 out of 9 samples.

In the males' lie sample, 26 patterns were found, of which 6 patterns are complex (23%). The event-types included in these patterns contain au45-gaze combinations and combinations of illustrator gestures and head shakes (see Figure 21). More patterns included leg movements and posture shifts, also combined with head shaking and/or illustrator gestures. The most complex pattern has a length of 4 event-types.

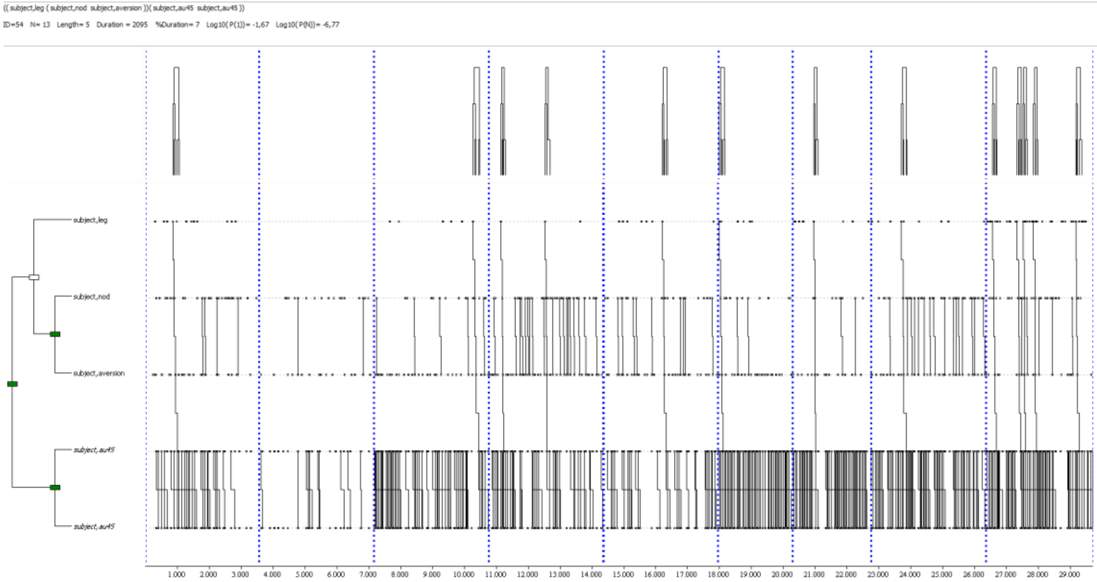

Figure 22. This pattern has 3 levels and a length of 5 event-types. It begins with a leg movement, followed by nodding and aversion, then ends with two blinks (au45). It is distributed among 8 out of 9 samples.

In the females' truth sample, 37 patterns were found. Among them, 16 are complex (43%). These include gaze-au45 combinations with leg movements, as well as nodding and posture shifts (see Figure 22). The most complex pattern has a length of 5 event-types.

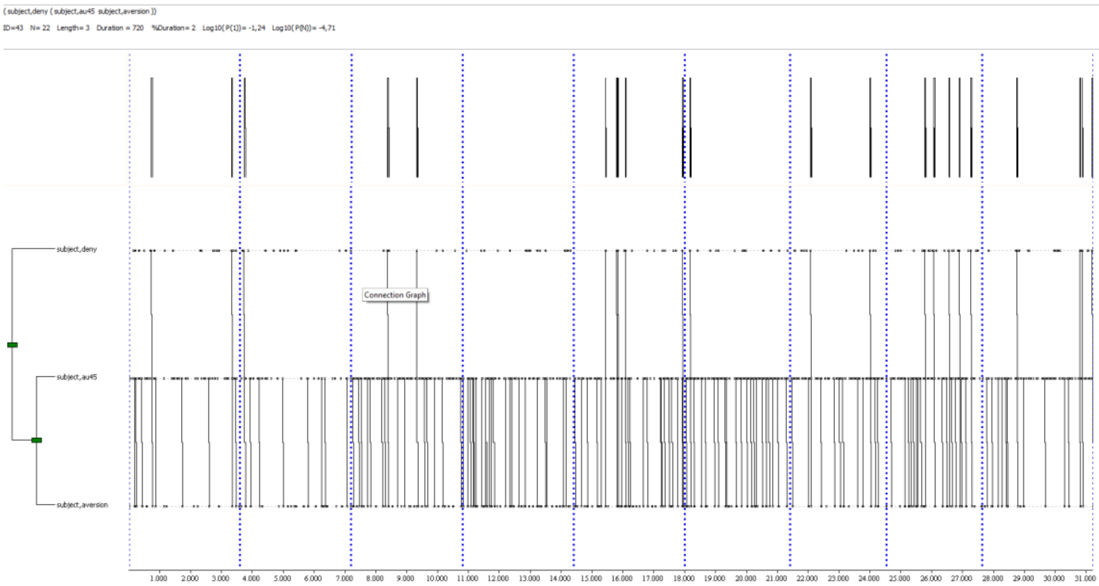

Figure 23. This pattern has 2 levels and a length of 3 event-types. It begins with head shaking, followed by blinking (au45) and aversion. It is distributed among 8 out of 9 samples.

In the females' lie sample, we detected 49 patterns; 25 of these are complex (51%). They contain gaze-au45 combinations with nodding and head shaking (see Figure 23), also combined in patterns including rhythmic gestures.

7.5.3 Post-hoc control

None of the participants resulted as an outlier relatively to the variables taken in consideration (state anxiety, trait anxiety, phonological working memory, and visuo-spatial working memory). Some statistics of possible interest for this work are reported next.

Test dei contrasti entro soggetti						
Misura:	STAI_S					
Sorgente		Somma dei quadrati Tipo III	df	Media dei quadrati	F	Sig.
state_anxiety	Lineare	74,014	1	74,014	2,011	,165
state_anxiety * CONDITION	Lineare	3,125	1	3,125	,085	,773
Errore(state_anxiety)	Lineare	1251,361	34	36,805		

Table 6. Within subjects contrast test.

Test degli effetti fra soggetti					
Misura:	STAI_S				
Variabile trasformata:	Media				
Sorgente	Somma dei quadrati Tipo III	df	Media dei quadrati	F	Sig.
Intercetta	#########	1	#########	905,056	,000
CONDITION	100,347	1	100,347	,883	,354
Errore	3863,028	34	113,618		

Table 7. Between subjects effects test.

Tables 6 and 7 show the results of a repeated measures ANOVA, aimed at verifying that state anxiety did not increase significantly in the second part of the experiment and that did not vary according to the experimental condition.

As we can see, none of the tests are significant.

Test per campioni indipendenti										
		Test di Levene		Test t di uguaglianza delle medie						
									Intervallo di confidenza per la differenza al 95%	
		F	Sig.	t	df	Sig. (2-code)	Differenza fra medie	Differenza errore standard	Inferiore	Superiore
CORSI	Assumi varianze uguali	1,852	,183	2,016	34	,052	,76780	,38093	-,00634	1,54195
	Non assumere varianze uguali			2,033	33,952	,050	,76780	,37766	,00027	1,53533
CIFRE	Assumi varianze uguali	,004	,951	,672	34	,506	,22291	,33165	-,45109	,89691
	Non assumere varianze uguali			,672	33,571	,506	,22291	,33162	-,45135	,89717
STAI_T	Assumi varianze uguali	,007	,935	-1,563	34	,127	-3,58204	2,29246	-8,24089	1,07680
	Non assumere varianze uguali			-1,570	33,962	,126	-3,58204	2,28190	-8,21961	1,05553
STAI_S1	Assumi varianze uguali	8,369	,007	-1,304	34	,201	-3,14551	2,41248	-8,04827	1,75725
	Non assumere varianze uguali			-1,352	26,257	,188	-3,14551	2,32646	-7,92534	1,63432
STAI_S2	Assumi varianze uguali	8,268	,007	-2,386	34	,023	-7,32198	3,06867	-13,55827	-1,08570
	Non assumere varianze uguali			-2,475	26,073	,020	-7,32198	2,95793	-13,40127	-1,24269
STAI_S_TOT	Assumi varianze uguali	6,494	,016	-2,194	34	,035	-5,23375	2,38548	-10,08162	-,38587
	Non assumere varianze uguali			-2,272	26,828	,031	-5,23375	2,30361	-9,96178	-,50572

Table 8. Independent samples t-test.

Tables 8 and 9 show the results of an independent samples t-test, aimed at verifying a possible gender effect upon considered variables and their means.

Statistiche di gruppo					
GENDER		N	Media	Deviazione std.	Errore std. Media
CORSI	MALE	17	6,2941	1,04670	,25386
	FEMALE	19	5,5263	1,21876	,27960
CIFRE	MALE	17	6,1176	,99262	,24075
	FEMALE	19	5,8947	,99413	,22807
STAI_T	MALE	17	40,4706	6,56808	1,59299
	FEMALE	19	44,0526	7,12175	1,63384
STAI_S1	MALE	17	35,1176	4,28489	1,03924
	FEMALE	19	38,2632	9,07280	2,08144
STAI_S2	MALE	17	34,9412	5,39062	1,30742
	FEMALE	19	42,2632	11,56548	2,65330
STAI_S_TOT	MALE	17	35,0294	4,37847	1,06193
	FEMALE	19	40,2632	8,91062	2,04424

Table 9. Means per gender.

We observe that the only significant difference is the one related to the Corsi test (visuo-spatial working memory), where males gave better performances. We hypothesize the positivity of the Leven Test for STAI_2 and STAI_S_TOT depend mainly on the small sample size. We believe, therefore, that even though the significance of the t-test is neutralized from the Leven test significance, the differences in means are still an interesting data. It would seem, indeed, that females had experimented a higher state anxiety than males, independently of experimental condition.

7.6 DISFLUENCY CUES

7.6.1 Data analysis

The first step was creating a corpus containing all the transcriptions related to true and false reports of our 36 participants, considering the two minutes corresponding to the observational period set in the previous analyses.

Since we wanted to verify the presence of linguistic material which would signal a process of strategic planning or on-line planning (Wendel, 1997), we considered empty pauses, full pauses and other discourse markers that have functional value and don't belong to a morphologic or lexical class (Leoni & Giordano, 2005). The empty pauses are periods of silence and can be intentional (like emphasis, junction, syntactical, or control pauses) or unintentional (breathing or programming pauses). Non-silent pauses are phenomena of disfluency related to processes of on-line speech planning (e.g. *ehm*, *uhm*, prolonged vocals at words' terminals and so on). The other discourse markers considered, instead, belong to various classes such as adverbs (e.g. *allora*, *insomma, quindi*), verbal forms (e.g. *diciamo, penso*) or whole linguistic expressions (e.g. *per così dire*)

Therefore, we identified the following classes of markers:

- Pauses (full and empty pauses);
- Discourse markers;
- Discourse markers and pauses (pause + adverb, pause + verb, verb + pause, adverb + pause).

7.6.2 Results

COGNITIVE LOAD	VERACITY STATUS	PAUSES	DISCOURSIVE SIGNALS	DISCOURSIVE SIGNALS + PAUSES
CONTROL	TRUTH	497	581	41
CONTROL	LIE	616	608	59
EXPERIMENTAL	TRUTH	453	494	22
EXPERIMENTAL	LIE	524	553	40

Table 10. Results for the analysis on single markers.

Table 10 shows the results of the analyses on single markers. We consider all values listed as simple indications because it was not possible to run a statistical detection of significance.

Pauses. Deception is characterized by a bigger number of pauses than truth, independently of the experimental condition. The manipulation of cognitive load did not elicit significant differences.

Discourse markers. In the control condition, there are no differences between truth and lie in the frequency of other discourse markers. In the experimental condition, the frequency seems to be slightly higher in lying data, but it is a minimal variation. Overall, we can say manipulation of cognitive load brought to a decrease of these markers in both conditions.

Discourse markers and pauses. In the control condition, this marker seems to be more frequent during deception. In the experimental condition, the tendency is similar, but there is a decrease of this marker in both truth and lie, and, furthermore, the difference between the two conditions increases.

In this analysis as well, we took in consideration a possible gender effect. Results follow.

Pauses (see Figures 24 and 25). In the control condition, there are more pauses in lying data than in true telling data in both genders. In males, this difference appears to be sharper. Females show an overall number of pauses that is higher than in males in both conditions.

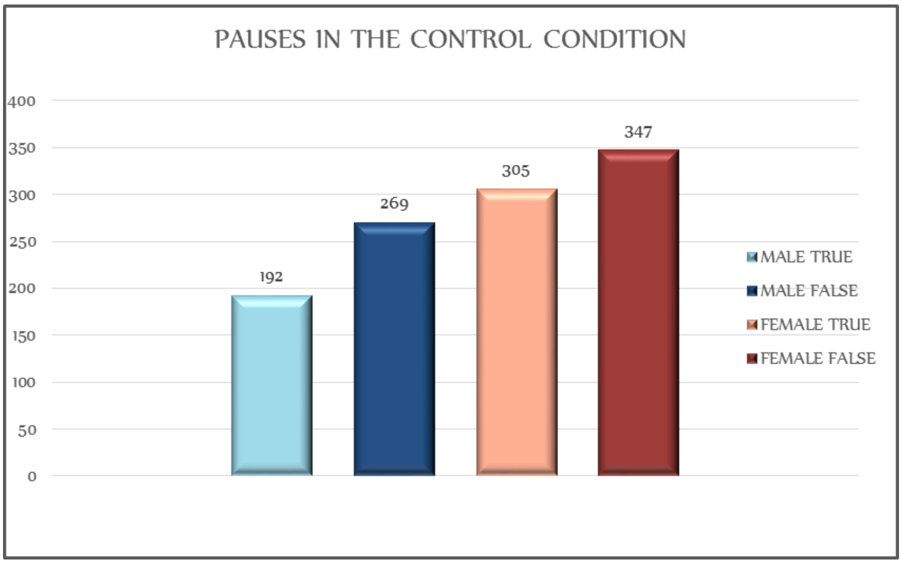

Figure 24. Number of pauses in the control condition.

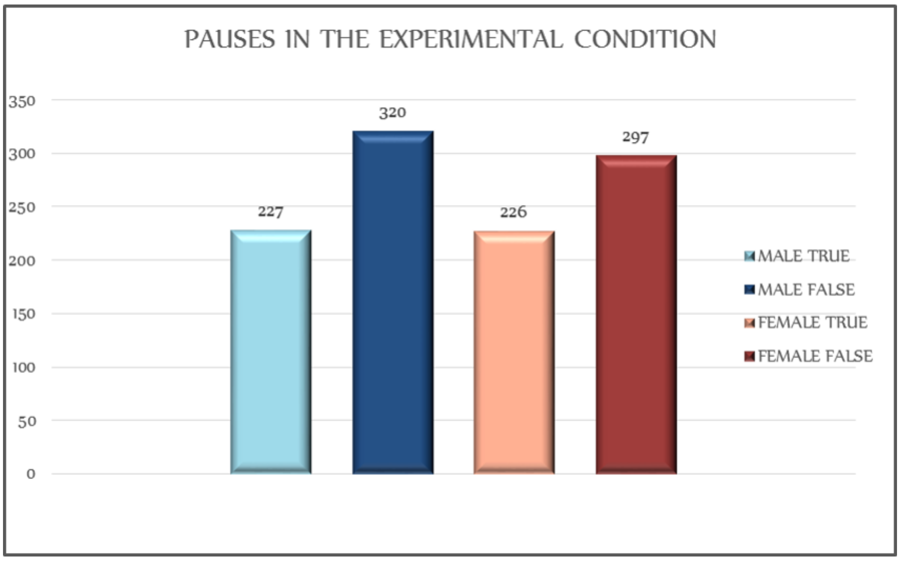

Figure 25. Number of pauses in the exerimental condition.

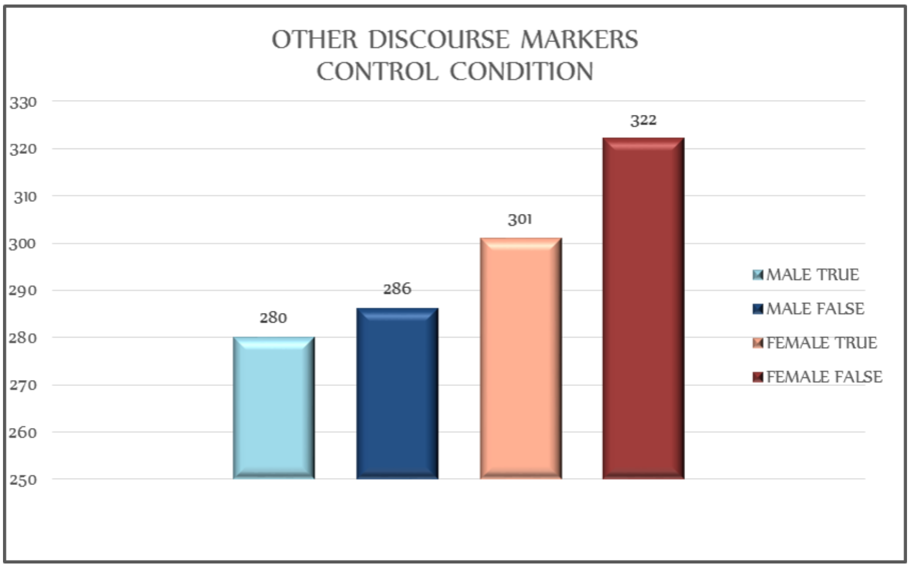

Figure 26. Number of other discourse markers in the control condition.

Discourse markers (see Figures 26 and 27). In the control condition, given the lack of significant differences between truth telling and lying detected in the aggregate sample, we can notice that males, in general, show a minor frequency of these markers in both conditions. In the experimental condition, there are no sensible gender effects compared to the aggregate data.

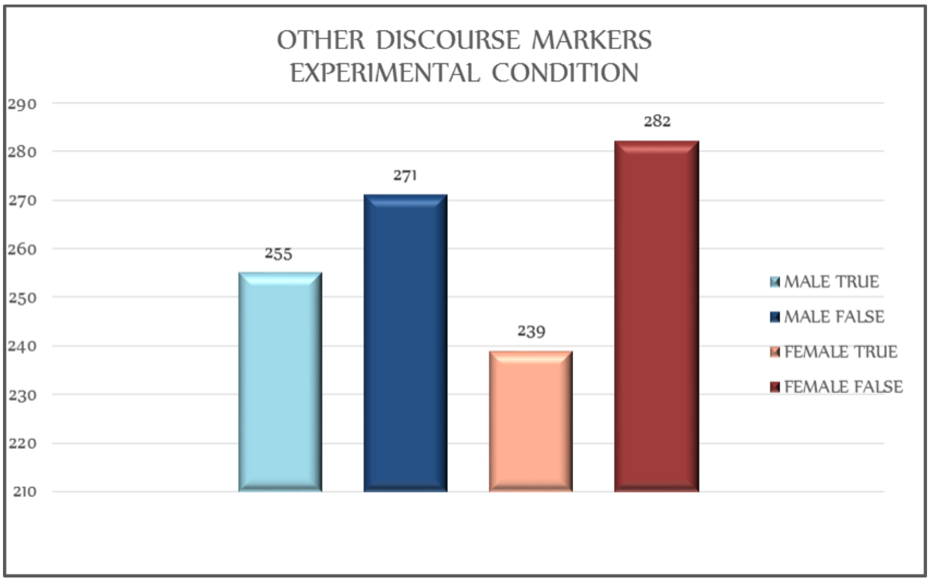

Figure 27.Number of other discourse markers in the experimental condition.

Discourse markers and pauses (see Figures 28 and 29). Differences between truth telling and lying are similar in both genders in the control condition, with the same tendency showed in the aggregate sample (a higher frequency of the marker in lying). In the experimental condition, frequencies of this marker have different tendencies in both genders. There is no difference between truth telling and lying in females, while, in males, the difference is quite strong, in favor of lying.

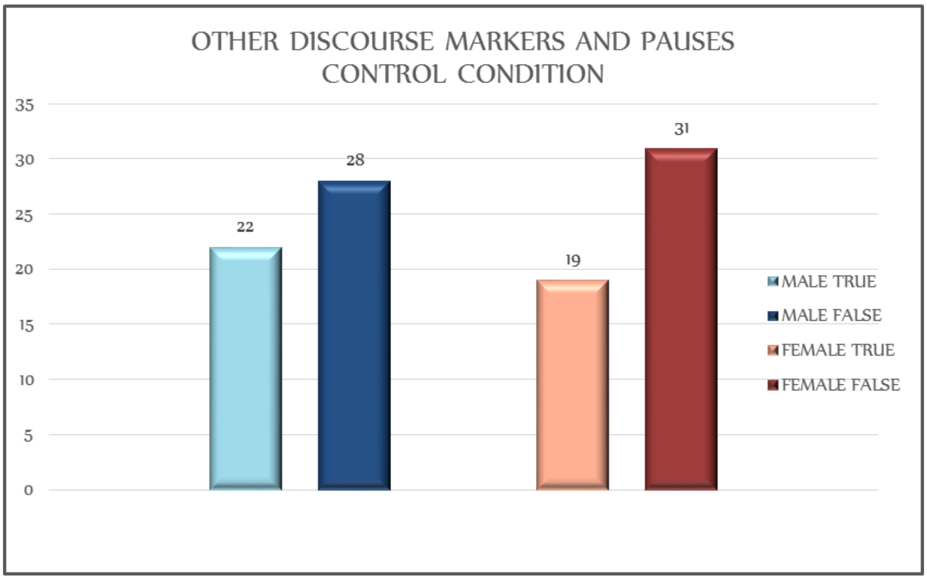

Figure 28. Number of other discourse markers + pauses in the control condition.

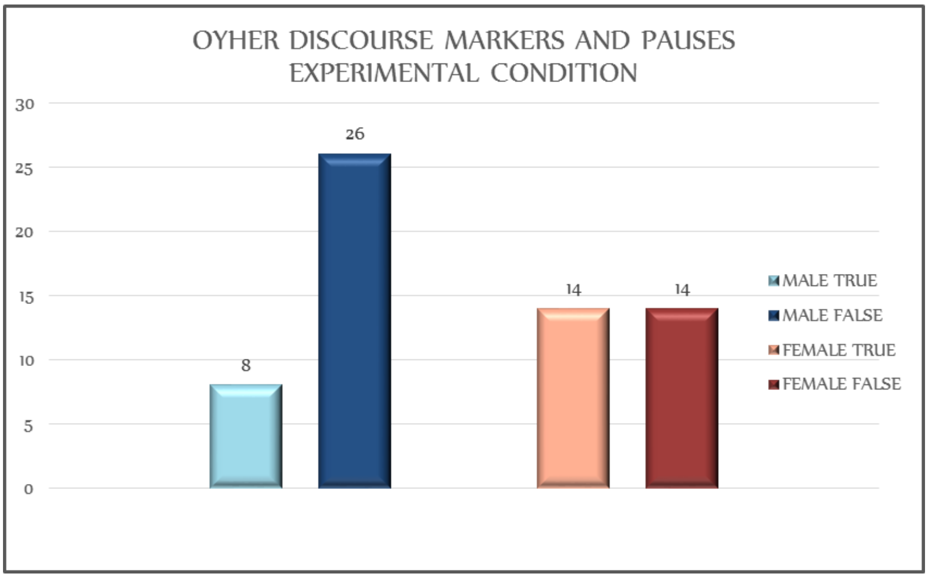

Figure 29. Number of other discourse markers + pauses in the experimental condition.

7.7 DISCUSSION

This study has taken in consideration two kinds of investigations, the one on nonverbal visual behaviors, conducted within a t-pattern methodology, and the one on nonverbal vocal behaviors, focused on an analysis of disfluency signals through NOOJ software.

We will now discuss both.

Like we said for the pilot study, t-pattern analysis is an unexplored methodology in this field of application. The results of this research will now be discussed by putting them in relation to traditional literature about deception detection and the results of the pilot study, the only truly comparable data.

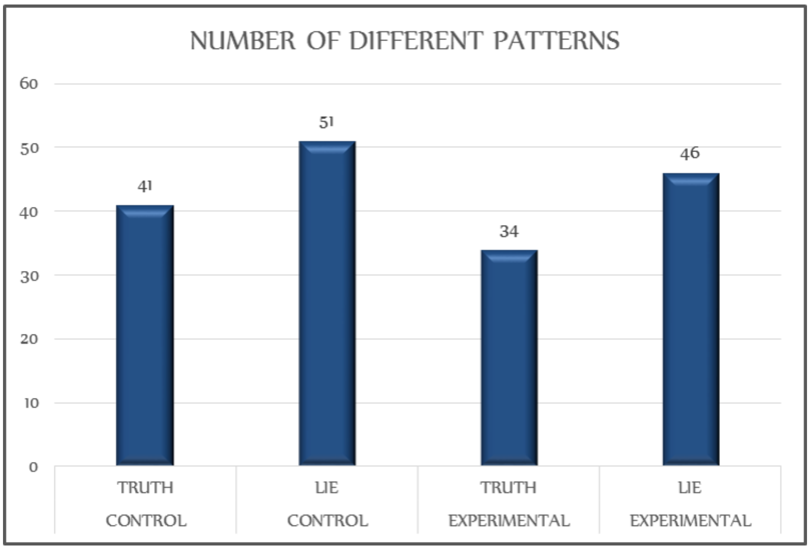

Figure 30. Number of different patterns.

Concerning the first analysis: the number, variety, and complexity of patterns have a similar tendency in both conditions (see Figures 30, 31 and 32), which means they are greater in lying data than in truth telling data. This tendency is the opposite of what has been observed in the pilot study, where the control condition was characterized by less patterns, variety, and complexity in lying data than in truth telling data.

The manipulation of cognitive load seems to have provoked a slight decrease in all parameters, though keeping the relation between truth telling and lying data unaltered. It would seem, therefore, that it might have acted similarly in both situations, creating the same level of interference.

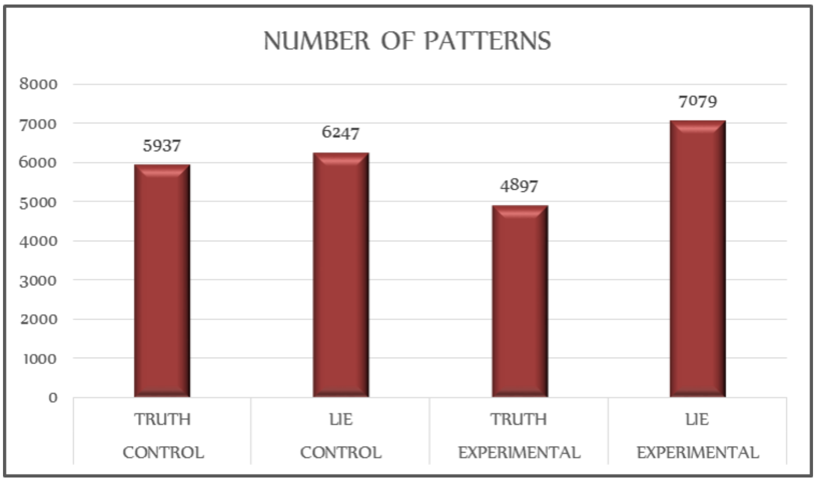

Figure 31. Number of patterns.

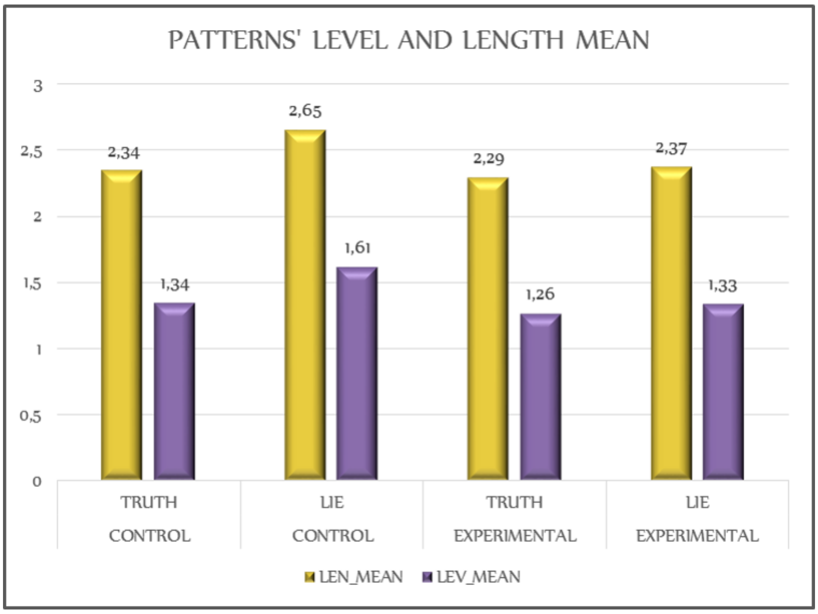

Figure 32. Pattern's level and length mean.

Concerning the event-types that compose patterns: in the control condition, truth data and lying data include quite similar behaviors; it is important pointing out that lying data are characterized by a higher frequency of leg movements and posture shifts, even though literature has not identified a significant link between these indicators and deception, currently. In the experimental condition, much like the control one, there are no sharp differences, though we can notice how head shaking does not appear in truth telling patterns, while lying data are characterized by a higher frequency of rhythmic gestures.

The results of this first analysis, overall, would bring us to reject the first two hypotheses.

Now, we move on to the second analysis, which takes into account a possible gender effect. The results in Table 5 are surprising, to say the least. In the control condition, the two genders have an opposite tendency. Females-related data follow what was already gathered in the pilot study (in which females only composed the sample only), that is, truth being characterized by a higher number, variety, and complexity of patterns than lie (see Figure 33, 34, and 35).

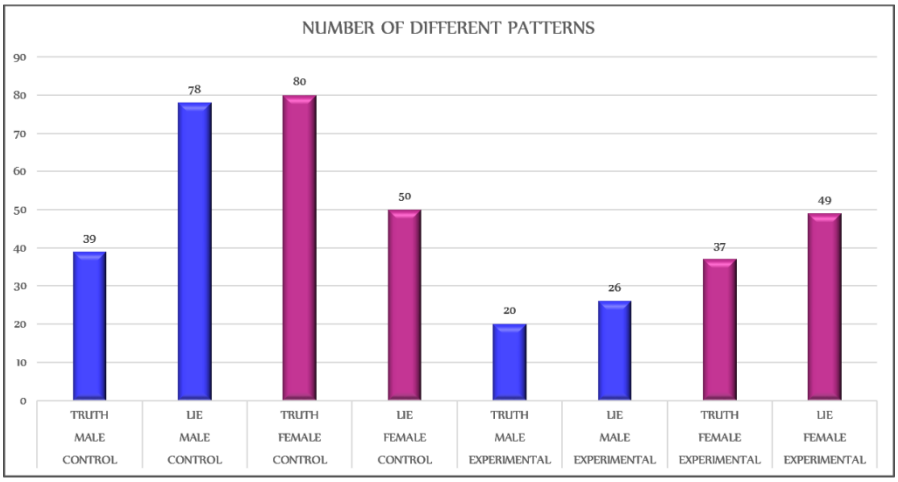

Figure 33. Number of different patterns by gender.

On the contrary, males have a much higher number, diversity and complexity in patterns related to lying (see Figure 33, 34, and 35). In light of this data, a gender difference in the organization of behavior between truth telling and lying seems to be strong, highlighting the limits of the pilot study, which seems to be indicative only of the female population.

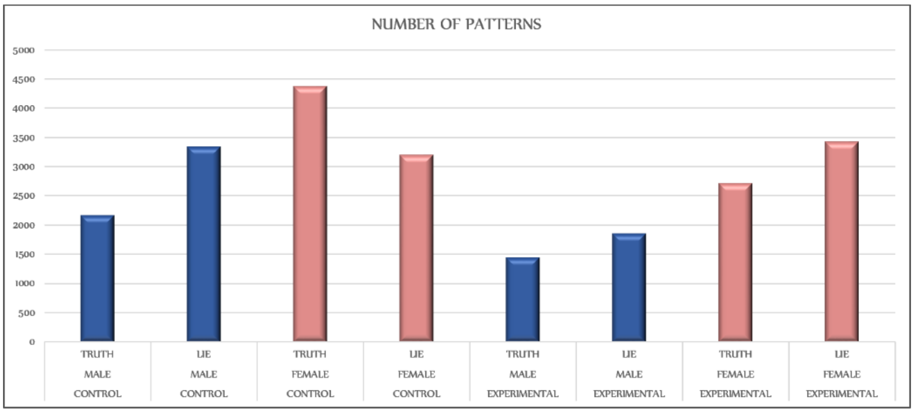

Figure 34. Number of patterns by gender.

Concerning the experimental condition: in truth telling, the manipulation of cognitive load provokes the same effect in both genders, meaning a decrease in number, variety, and complexity of patterns (see Figures 33, 34, and 35). This effect is stronger in females, where parameters get halved. In lying, the interference of the secondary task seems to have had no effect on females while it brings down number, variety, and complexity of patterns in males. In this case, gender difference seems to be quite strong as well. Given the lack of a literature which could support us in the interpretation of this data, we can only try and formulate hypotheses.

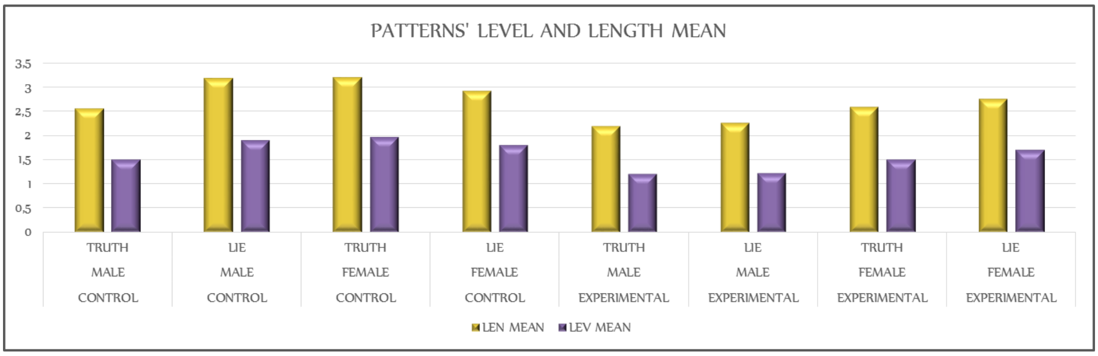

Figure 35. Patterns' level and length mean by gender.

It would seem that, concerning females, the dual task procedure has provoked an interference only in one condition (truth telling), while it has not disturbed the execution of the lying task.

As we have seen in chapter 3, the interference provoked by a dual task is directly proportional to the overlapping between perceptive and motor systems used for the execution of both tasks (Meyer & Kieras, 1997; Meyer et al., 2002). This overlap, in our case, seems to happen in both conditions for males, suggesting how perceptive and motor systems used to tell the truth and to lie are nearly the same. In females, instead, a possible hypothesis concerning the lack of interference for the second task during deception, could be in a missed overlap between processing systems dedicated to the execution of both tasks. If so, we could hypothesize that, in females, telling the truth and lying rely on different perceptive and motor resources, or at least less conflicting than in males.

Furthermore, as we already have seen in the manipulation check results related to state anxiety, females present higher values than males independently of the experimental condition, with significant differences in total state anxiety and, more specifically, in the state anxiety related to the second part of the experiment. Males, instead, gave a better performance in visuo-spatial memory. It is reasonable hypothesizing that both these variables have a role in explaining gender differences related to behavioral patterns in deception. Nonetheless, we are not able to formulate hypotheses about the way this influence could happen with the data in our possession.

Concerning the events composing the detected patterns: in the control condition, both males and females present a complexity that makes it hard to qualitatively discriminate between truth telling and lying. While differences in number, variety and complexity are evident, we don't notice the same thing in the observation of single behaviors composing patterns.

In males, we can notice that the more complex patterns related to lying do not include blinking, which is consistent with literature that links a decrease in the frequency of this behavior with the increase of cognitive load (Sporer & Schwandt, 2007).

In females, we find symbolic gestures and feet movements only in truth telling data. Within lie-related patterns, nodding and illustrator gestures disappear, while we can find adaptors; these latter cues are also consistent with literature (Vrij, 1997, 2008; Sporer & Schwandt, 2007).

In the experimental condition, a few more difference emerge in the composition of patterns. In females, truth is characterized by a higher frequency of leg movements and postural shifts, while head shaking (which appears in lie-related patterns) is not present. In lying data, furthermore, the frequency of rhythmic gestures is higher.

In males, truth data include few blinking (au45) and aversion patterns, while adaptor and rhythmic gestures are more frequent. Deception, instead, is characterized by a higher number of illustrators, head shaking and leg movements. The presence of a higher number of illustrator gestures is not consistent with literature (Vrij et al., 1997), even though some authors underline that skilled liars might use more illustrators on purpose in order to appear credible (DePaulo et al., 2003).

Overall, the results of this second analysis indicate how, presumably, the insufficient differences found in the first one could be tied to an important gender effect.

Basing on what has been done until now, thence, it would seem the organization of behavior in males and females when they lie and when they tell the truth (translated into features of the t-patterns detected) is too different to consider aggregate data.

Reconsidering our hypotheses in light of this, we can say that, as for females, the first hypothesis is supported. In the control condition, indeed, as in the pilot study, number, variety, and complexity of patterns decrease in deception. We reject, instead, the second hypothesis, because the dual-task procedure, interfering with truth telling only, brings down differences between truth telling and lying that are clear in the control condition.

For what concerns males, instead, we reject both hypotheses since, in both conditions, number, variety, and complexity of patterns are higher in lying data than in truth telling data (even if the difference is minimal in the experimental condition) and the manipulation of cognitive load provokes a flattening of almost all differences.

Concerning the second investigation, related to disfluency cues; as disfluency signals, like we said earlier, we decided to consider three markers: pauses, other discourse markers and discourse markers + pauses. The results of this analysis show that, in general, markers of disfluency are higher in lying than in truth telling, in all conditions.

This result is consistent with literature affirming how these markers are tied to an increase in cognitive load, higher in deception conditions (Vrij, 2005; Vrij & Mann, 2001; Yuan & Ellis, 2003) and allows us, with due caution in this condition, to partially support the third hypothesis.

For what concerns the effects of cognitive load manipulation, we can affirm that, in general, it provokes a decrease in 2 markers out of 3, the other discourse markers and the discourse markers + pauses, while it seems to have no effect on pauses. These results are controversial and lead us to reject the fourth hypothesis with the same reserve mentioned in confirming the third. In fact, we need to remind how this kind of analysis and the sample size did not allow us to obtain measure indicators statistically significant.

As for gender differences, we can only acknowledge the detected differences, giving them an exclusively descriptive value. In fact, there is no literature related to a gender effect on disfluency markers in deception.

7.8 CONCLUSIONS

This study had four objectives. The first was to verify if the differences detected in the pilot study (in nonverbal behavior patterns between lying and telling the truth) are found in the current study as well. As we have seen in the discussion paragraph, the results of this study as well highlight important and significant differences in the organization of nonverbal behavior of liars and truth tellers, but they are characterized by a strong gender effect.

It would be quite an impact if this data were to be confirmed by further studies, but it is necessary knowing which are the factors, related to gender differences, that influence behavioral patterns. Further studies, not disregarding gender as independent variable, should keep under control variables such as motivation, the way of lying, and personality factors. Literature about gender differences in deceivers agrees on affirming there are no significant differences in the frequency of lying in females and males or in behavioral cues (apart from a study by Cody and O'Hair in 1983). In general, however, there seems to be a difference in the reason why the two genders lie. Women, indeed, use mostly cooperative deception, while males lie more frequently for selfish reasons (e.g. Vrij, 2008).

Therefore, we can affirm that our first objective has been reached; there are differences, especially for what concerns structural features of behaviors such as organization, richness, and complexity; the differences found between truth telling and lying call for further exploration, taking into account specific behaviors that compose patterns. In fact, although we detected that some behaviors appear with different frequencies in patterns belonging to one or the other condition, it would seem that a "Pinocchio's nose" should be looked for in the overall structure of behavior, rather than in the single systems composing it.

As for the second objective, that is finding differences in paraverbal cues of disfluency, we can say that, considering the limits of the study which will be discussed next, it has been partially reached. Deception, confirming what we found in literature, is generally characterized by a higher number of disfluency cues, given by a higher intrinsic cognitive load.

We get to the third objective, evalutating the efficacy of the memory task for sentences. In this case the objective seems to be reached, even though results do not go in the direction we hoped. This task did not provoke the desired interference and, furthermore, it seems to have acted differently on males and females. Regarding this matter, it would be interesting exploring if this gender difference of the interference depends from a mistaken decision about the task choice or from the involvement of different perceptual and motor processing systems in males and females when they tell the truth or lie. This hypothesis is very fascinating and calls for further studies that, as already said, should control different variables, first among them the kind of lie observed in the study. We are to this moment convinced that a dual-task procedure is the most interesting solution to explore for this kind of research, but it is necessary to test other secondary tasks in order to find one that allows increasing the differences between truth telling and lying producing data that are easier to interpret compared to the control condition.

Furthermore, we underline how T-pattern analysis allowed to find significant differences between truth telling and lying even without operating any kind of manipulation; the need within this methodology, therefore, seems to be simplifying the interpretation of the most complex patterns, without provoking a flattening of all differences. In relation to the last objective, thence, we can confirm a promising start of t-pattern analysis as an instrument in deception detection.

We now consider the limits of this study. First of all, we have to mention and underline the small size of the sample, which became evident especially in light of results on gender differences. Moreover, increasing the length of the observation period might be useful, since, not having limited our participants in the duration of their accounts (to let them have most freedom possible in choosing how and what to say, at which speed, and so on), and having to analyze comparable samples, we had to calibrate the observation period to the minimal duration of the collected data. In a future research, a modification of procedure could consist in using a confederate to prolong the report's duration.

Furthermore, as we already said, some variables such as motivation and kind of lie have not been taken in consideration; in light of the results obtained, a follow-up to this research could be enhanced by the use of an experimental design which considers them as independent variables.

The analyses on paraverbal systems should be improved, and it would be useful to extend this research to verbal behavior, in order to fully exploit the advantages of multimodality in deception detection. Furthermore, we cannot exclude that non-detected differences in nonverbal behaviors might have been happened on verbal behaviors, since, especially in high cognitive load conditions, individuals might become less efficient in control and management of a system rather than another.

Summing up, this study offers important prompts and cues on the prosecution of research in this field, and, with this methodology, reminding it is a still unexplored area, but that, considering the first results, promises to be able to represent a useful block in the extremely complex puzzle of deception detection based on human behavior.

CONCLUSION

The aim of this work was to propose a new approach to deception detection, which would help to find significant differences in behavior between liars and truth tellers. This approach was based on the combination of three factors: cognitive load manipulation, multimodal data collection, and t-pattern analysis.

We believe that, despite all difficulties cause by novelty and complexity, this area seems to deserve further exploration.

Manipulation of cognitive load, especially, through a dual-task procedure, allows gathering important information about cognitive processes underlying production, enunciation and real-time monitoring of deceptive communication.

The advantages of a multimodal approach are already acknowledged in literature about deception detection and on everything that concerns the understanding of any communicative phenomenon. We believe a methodology such as t-pattern analysis is able to get the best advantages from an approach that combines data coming from multiple signaling systems, therefore unveiling the complex structure at the basis of the organization of human behavior.

In a research domain with such important fallout upon people's lives, we believe that the methodology proposed in this context might offer a potentially valid help. For this to happen, a great amount of research work and diffusion is necessary to allow constructing a solid literature basis through which it would be able to read and re-interpret the results.

This work has two kinds of impacts: first of all, it gives important indications and new starting points for base research upon the understanding of deception and the mechanisms regulating it; furthermore, it has important applicative fallouts in terms of individuals' security and, therefore, personal but, especially, social and public wellbeing.

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