UNIVERSITA' DEGLI STUDI DI PADOVA

Dipartimento di Psicologia Generale

Corso di Laurea Magistrale in Psicologia Clinica

Tesi di Laurea Magistrale

LYING TO IDENTITY: ANALYSIS OF LATENCIES FROM INTERVIEWS

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ANNO ACCADEMICO 2023 – 2024

INDEX

INTRODUCTION

Although we often may not be consciously aware of it, deception is a highly prevalent phenomenon in everyday interactions (DePaulo et al., 1996), making it difficult to discern whether the person we are engaging with is being truthful or not.

This thesis focuses on a specific type of deception known as *identity deception*, where individuals intentionally hide their original identity, assume the identity of someone else, or employ forged identity documents, thereby compromising the reliability of identity information due to deliberate deceit (Wang et al., 2004; 2006). *Identity deception* is commonly observed in contexts such as the internet (Caspi & Gorsky, 2006; Drouin et al., 2016), often with malicious intent, such as occurs in *child grooming* (Cano et al., 2014). Identity liars represent a significant security concern, even at the national level, given that terrorists and criminals frequently succeed in crossing international borders by circumventing airport security checks using counterfeit documents. Consequently, the use of false identifiers has become a common element in various criminal activities, including organized crime, terrorism (Boongon et al., 2010), human and drug trafficking, large-scale fraud, alien and weapons smuggling, and money laundering (Gordon & Willox, 2003). Effectively monitoring and preventing criminal activities necessitates the accurate identification of offenders, who often possess multiple counterfeit names, dates of birth, addresses, bank accounts, phone numbers, and email accounts (Boongoen et al., 2010). According to Frontex (2011) there was a 20 percent increase in the detection of fraudulent documents at Europe's external borders between 2009 and 2010, indicating a noticeable upward trend in this phenomenon. The speed at which these deceptive identities evolve calls for solutions to detect identity deception.

The aim of this study is to validate the *unexpected questions technique* as a *lie detection* method, even in the context of face-to-face investigative interviews, aimed at exposing identity deceivers. In the field of *lie detection*, it is well-established that a pre-planned lie is nearly indistinguishable from the truth (DePaulo et al., 2003; Zuckerman et al., 2003). Deceivers, if given the opportunity, prepare in advance for a potential interview, considering the possible questions they may face (Hartwig et al., 2007). Liars adopt this strategy to reduce their cognitive load during the interview and appear credible to avoid detection. As deception becomes highly practiced, the cognitive load of deceivers is nearly identical to that of truthful individuals, and their responses do not contain the cues to deceit outlined in the literature, including indicators like reaction times (RTs) and errors (Van Bockstaele et al., 2012; Hu et al., 2012).

Given that cues indicative of deceit are scarce, diagnostically unreliable, and inconsistently manifested (DePaulo et al., 2003), research on deception detection has shifted its focus towards the strategic implementation of specific interview techniques designed to disproportionately burden liars relative to truth-tellers. Liars' increased cognitive load will reflect itself in his verbal and nonverbal behavior, thus eliciting the most differential responses between truth-tellers and liars that are diagnostic of deception and therefore increasing the ability to detect deception by attending to signs of cognitive load (Masip & Herrero, 2015; Parkhouse & Ormerod, 2018). This heightened manifestation of such indicators is particularly observable in individuals engaging in deception, as their cognitive resources are already partially depleted due to the act of lying. Truth-tellers likewise will undoubtedly experience an increased cognitive load (Parkhouse & Ormerod, 2018), nevertheless, unlike liars, this heightened cognitive load will not be substantial enough to result in a significant deterioration in their performance. This new approach is referred to in the literature as the *Cognitive Load Approach* (CLA) (Vrij et al., 2006; 2012; Walczyk et al., 2013; Blandón-Gitlin et al., 2014; Masip & Herrero, 2015).

One of the most commonly implemented techniques within this approach is the use of unexpected questions. This technique effectively exploits differences in the cognitive load experienced by truth-tellers and liars, thereby increasing the lie detection accuracy by accentuating the differences in their verbal and nonverbal behavior (Vrij, 2014; Warmelink et al., 2012; Sooniste et al., 2016). When confronted with unexpected questions, liars lack the time to plan a lie. They must invent on the spot an answer, inhibit the true response and substitute it with the lie, and finally mentally verify that the lie is not easily detectable by the interlocutor. These complex mental operations required of liars, stemming from the information reconstruction process triggered by unexpected questions, result in a higher cognitive load. This heightened cognitive load leads to longer response times and reduced response accuracy, rendering slowness and inaccuracy in answering unexpected questions as diagnostic indicators of lying (Parkhouse & Ormerod, 2018). In contrast, truth-tellers experience relative similar levels of cognitive load when answering to expected and unexpected questions because they can draw upon real memories of events, resulting in more comparable answers to these two kinds of questions (Vrij, 2014).

To assess this hypothesis, we designed an interview that included unexpected, expected, and control questions. Participants were instructed to provide responses using either their genuine personal information or fictitious identities that were assigned to them. Subsequently, we measured response times and recorded any errors made during the response time frame. Control questions are those to which even deceivers are compelled to respond truthfully, as the correctness of the response is directly verifiable by the interviewer. These questions allowed us to establish a *truth baseline* (Vrij, 2008; Palena et al., 2018), indicating how much time and how many errors, on average, individuals commit when responding truthfully to a question. Expected questions, on the other hand, pertain to the topic of investigation, and the correctness of the response is not verifiable. Since these questions are anticipatable, deceivers can prepare their responses in advance, rendering them more comparable to those provided by truth-tellers. The central role in this procedure is played by unexpected questions—those questions that the respondent does not anticipate and, therefore, cannot prepare for in advance (Sartori, 2021). Consequently, unexpected questions can be considered as a *rehearsal averting strategy*, and the lengthening of response times and the increase in error rates among individuals responding to these questions serve as some of the most effective diagnostic indicators of deception (Monaro et al., 2021).

To further increase the cognitive load on deceivers, questions can be presented randomly during the interview, making use of a concept recognized in academic literature as the *switch cos*t (Kiesel et al., 2010; Monsell, 2003; Vandierendonck, et al., 2010). In the interview administered in our study, questions were not presented in distinct categories (control questions followed by expected questions and then unexpected questions); instead, the order was randomized. This forced identity deceivers, in contrast to truth-tellers, to continuously switch between opposing cognitive strategies in response to the various question categories. The approach adopted in responding to both expected and unexpected questions involved suppressing truthful responses and substituting them with deceptive responses. Conversely, when dealing with control questions, the strategy was to provide honest answers. In contrast, for truth-tellers, the sole approach throughout the interview was to respond honestly. This is precisely why deceivers, compared to truth-tellers, perform an additional cognitive task known as *task switching*, resulting in an enhanced cognitive load known as the *switch cost*, which is reflected in liars' task performance, characterized by higher response latencies and error rates (Foerster et al., 2016).

In the first chapter, we will present several definitions and theories related to the construct of deception as they emerge in relevant literature. Subsequently, the focus will shift towards the cerebral regions and executive processes implicated in the generation of a lie. Following this, we will introduce a crucial distinction for the purposes of our research, namely the differentiation between rehearsed and unrehearsed lies. In light of this distinction, we will introduce a novel approach in the field of *lie detection*, namely the *Cognitive Load Approach* (CLA), and, specifically, the *unexpected questions technique*, which is employed in our study. In the second chapter, we will delve into a specific type of deception, namely *identity deception*, where individuals intentionally hide their original identity, assume the identity of someone else, or employ forged identity documents, thereby compromising the reliability of identity information due to deliberate deceit (Wang et al., 2004; Wang et al., 2006). The second part of the second chapter will introduce several new methods implemented in the deception detection domain to unmask identity liars. Moving on to Chapter 3, we will present our research study, providing a detailed description of the theoretical background from which the study emerged, its objectives, hypotheses, the sample used, the experimental procedure employed, the specific types of questions integrated into the interview, and the software utilized for both interview coding and results analysis. In Chapters 4 and 5, the study results will be presented, followed by a discussion, along with the limitations and future research directions.

CHAPTER 1: LYING, AN OVERVIEW OF THE RELEVANT LITERATURE

1.1 Lie definition

It is widely acknowledged that a lie occurs when one intentionally makes a false statement, and demonstrating the truthfulness of a statement is sufficient to counter accusations of lying. In everyday life, when we state something, the expectation is that we are communicating truthfully, thus lying primarily involves breaking an implicit promise to communicate truthfully (Stocks, 1932). However, making a false statement is a necessary but not sufficient condition for the construct of lying to exist, we must therefore add some building blocks to the lie construct.

Many people state things that are untrue, but that however does not mean we can consider their statements to be lies. A false information may be provided involuntarily, for example when the communicator cannot offer an accurate statement due to cognitive limitations, in this case we could not conclude that the sender is lying, since the alteration in the statements would not be volunteer and the liar may be unaware that the information provided is false (Masip et al., 2004). Since a liar cannot believe that the statement he makes is true, one missing piece in the definition of the lie construct is the liar's subjective awareness that what he or she is stating is false. When the communicator is capable of providing an accurate account but chooses not to do so, the inaccuracy is motivated by personal reasons, and we can classify the sender as a liar (Masip et al., 2004).

Given that, the fundamental property of the lie construct concerns the behavioral intention that directs the liar's behavior, who by lying deliberately intends to mislead the interlocutor. The latter feature is clearly spelled out in Ekman's definition of a lie, according to which "*lying is the deliberate intention to mislead another person by falsifying a truthful information*" (Ekman, 2009). Coleman and Kay (1981) definition summarizes and assembles all of the aforementioned features that a lie is required to have in order to be defined as such. According to the authors a lie occurs when a person (1) makes a false statement, (2) believes that is false or probably false (or alternatively doesn't believe that is true) and (3) intends to deceive another person by stating it (thus aiming to cause the other person to hold false beliefs). When all three conditions are satisfied, it is unequivocally a lie.

According to Masip and colleagues (2004) a lie can be defined as "*the deliberate attempt, whether successful or not, to conceal, fabricate, and/or manipulate in any other way factual and/or emotional information, by verbal and/or nonverbal means, in order to create or maintain in another or in others a belief that the communicator himself or herself considers false*". Following this definition, lies can be produced through two main strategies: *falsification* and *concealment*. *Falsification*, also known as *fabrication* or *deception by commission*, involves presenting false information as if it were true. *Concealment*, also referred to as *deception by omission*, entails withholding truthful and significant information. When lying, the deceiver is engaged in both concealing and fabricating processes (Zuckerman et al., 1981). In other words, when lying, one must convey a fabricated false message while simultaneously concealing the truthful information, all the while attempting to convince the recipient of one's sincerity.

Another important clarification to be made is that the motivation behind deception is not clearly the deceptive act itself, but rather the achievement of communication goals, which can benefit the communicator, the interlocutor, the relationship, or even a third party (Buller & Burgoon, 1996). These goals are accomplished through strategic manipulation of the conveyed information. McCronack's *Information Manipulation Theory* (IMT) (1992) identifies four main ways in which information can be altered: (1) manipulating the amount of information provided, as in *concealment*; (2) distorting the offered information, as in *falsification*; (3) presenting information in an equivocal or ambiguous manner; and (4) presenting information that is unremarkable to the preceding conversation. In sum, the deceiver may manipulate the quantity, quality, clarity, and relevance of the information provided to the interlocutor in order to achieve specific goals.

1.2 Theories of lying: an inherently cognitive demanding task?

Lying has been widely acknowledged as a cognitively complex task compared to truth-telling (Walczyk et al., 2003; Spence et al., 2001; 2004; Vendemia et al., 2005; Vrij, 2014). Several theories and models attempted to provide explanations for this greater cognitive complexity. The base explanatory provided by all these theories is that extra-cognitive demand is caused by liars having to perform some additional tasks.

Lane and Wagner's (1995) *Preoccupation Model of Secrecy* presents a cognitive framework to understand the cognitive load associated with *lies of omission*, wherein individuals withhold the truth. According to this model, *lies of omission* involve a cyclical process, where (a) the act of keeping a secret leads to thought suppression, (b) thought suppression results in intrusive thoughts, (c) intrusive thoughts prompt renewed efforts at thought suppression, and (d) this circular repetition of actions continues. The model posits that thought inhibition represents an active mental control strategy employed by individuals attempting to maintain a secret, and paradoxically, this attempt may render the secret thought more accessible cognitively. However, it is important to note that this model has certain limitations. Specifically, it does not account for the executive processes involved in fabricating a plausible lie. These executive processes encompass higher-order cognitive functions such as directed attention, planning, metacognition, manipulation of useful data in conscious working memory, inhibition of a prepotent response and activation of appropriate ones (Gombos, 2006). Therefore, while the *Preoccupation Model of Secrecy* provides valuable insights into the cognitive aspects of lies of omission, it does not offer a complete understanding of the full cognitive complexities involved in deceptive behaviors.

Carriòn et al. (2010) argued that cognitive control processes during deception cannot be simply reduced to the need to inhibit a tendency to state the truth. Instead, the authors proposed that lying represents a cognitive challenging task due to the presence of cognitive conflict arising from the need to simultaneously consider the mental states of others while deceiving them. As a result, the deceiver is required to hold two mental states in mind: their own perspective and that of the person they are attempting to mislead. Furthermore, the findings from Carriòn and colleagues' study (2010) indicated that participants who performed better on a mentalizing task, which involves understanding and predicting others' thoughts and intentions, experienced more conflict during the lying task. This suggests that individuals with superior mentalizing skills may encounter challenges in effectively deceiving others, as their heightened ability to comprehend the mental states of others might interfere with their deceptive abilities.

From a *Self-Presentational* perspective (DePaulo, 1992) lies are frequently employed as a means to achieve identity-related goals. A liar, in order to implant a false belief in another person, must exercise careful management of their own behavior and strategically utilize their social skills. According to DePaulo's *Self-Presentation Theory* (1992), liars are primarily preoccupied with presenting themselves as credible. As a result, they are more inclined to self-monitor, striving to control and suppress non-verbal cues that might indicate deception. Simultaneously, they attentively observe the interviewer for any signs of suspicion.

Buller and Burgoon (1996) *Interpersonal Deception Theory* (IDT) posits that when individuals engage in deception, they are concurrently involved in multiple tasks. They attempt to convey their deceptive message, while also monitoring the recipient of their deceptive account for any indicators of suspiciousness, and subsequently adjusting their behavior accordingly. Moreover, similarly to DePaulo (1992) *Self-Presentation Theory*, IDT asserts that deception involves behavioral and cognitive inhibition, as the deceiver must inhibit verbal and non-verbal cues to deceit to be perceived as believable.

Zuckerman's *Four Factor Theory* (1981) postulates that deception encompasses four main processes that influence deceiver's behavior. These processes include: (1) the liars' efforts to control their verbal and non-verbal behavior to appear honest, (2) generalized arousal, (3) experience of guilt, anxiety and other negative emotions and finally, (4) cognitive processing. Additionally, the deceiver must construct a deceptive message that avoids logical inconsistencies and contradictions with the listener's existing knowledge, and that is precisely why, according to this theory, lying requires more cognitive effort than telling the truth. In fact, the liar is tasked with maintaining both internal and external consistency within their deceptive narrative, ensuring that fabricated elements fit seamlessly together and align with the listener's knowledge.

Yet one other model that attempts to provide an explanation for the lying construction process is the *Activation-Decision-Construction-Action Theory* (ADCAT) proposed by Walczyk et al. (2003). This theory stands out as the only that provides a model of the cognitive foundation of the lie production process using response times (RTs), the time that elapses between the end of the examiner question and the beginning of the examinee response, as a cue to deceit, underlying the crucial role of executive processing in lie production. It is worth noting that the scientific community has already recognized the utility of reaction times in providing valuable insights into the cognitive demands inherent to a particular task (Stojmenova & Sodnik, 2018). ADCAT outlines the lie production process as follows: when a question is posed, *working memory*, containing memories and knowledge of the truth, is automatically activated. Subsequently, *decision-making* and *construction* processes come into play, determining whether to lie and how to fabricate the lie. According to Walczyk and colleagues (2003; 2009; 2014), providing a truthful response typically takes less than 400 milliseconds, as it involves retrieving truthful information *from long-term memory* to *working memory*. Conversely, responding deceptively requires the suppression of the truth, which is automatically activated, and the fabrication of a lie, leading to longer reaction times. The lengthening of RTs in lying can be attributed to two main cognitive processes: *inhibition* (necessary to suppress the initial automatic truth response) and the concurrent generation of an alternative deceptive response.

Walczyk and colleagues (2003) conducted an experiment to test the predictions of ADCAT. The researchers measured RTs for both autobiographical open-ended and yes-no questions. They found that both constructing a lie and deciding to lie required significantly longer RTs than telling the truth, with approximately 230 milliseconds longer for lying and 210 milliseconds longer for answering open-ended questions compared to answering yes-no questions. Furthermore, liars' verbal skills were correlated with their RTs, suggesting that lying is a constructive process dependent on participants' verbal efficiency. This verbal efficiency refers to their ability to access linguistic codes from semantic memory and manipulate them in working memory (Perfetti, 1985). Additionally, in self-reports provided by participants after the experiment, 35% of them revealed that they had to consciously inhibit truthful information before generating a lie.

Similarly, Spence and colleagues (2001; 2004) demonstrated that lying is associated with increased RTs, with lying responses taking 200 milliseconds longer than truthful responses. Lying was also correlated with slower speech, longer pauses, more speech disturbances, and fewer bodily movements, all of which serve as indicators of cognitive load. Also Vendemia et al. (2005) investigated the effects of deception related and response congruity related workload on RTs. They instructed participants to respond either truthfully or deceptively to true and false items concerning their own autobiographical information. The results indicated that deceptive responding generates longer RTs compared to truthful responding.

To summarize the findings from the reviewed scientific studies, it can be concluded that responding deceptively results in longer RTs, indicating that additional cognitive processing time is needed to inhibit the truth and fabricate a deceptive response. These results are in line with the understanding that RTs serve as a reliable measure of the cognitive load associated with a cognitive task (De Boeck & Jeon, 2019), helping to identify which task is more cognitively demanding. In the context of cognition-based *lie detection*, these findings suggest that the lengthening of response times, the delay in the subject's response when lying, may be one of the key features to distinguish lying responses from truthful ones.

Finally, Johnson and colleagues (2002) explored both the behavioral and neural aspects of truthful and deceptive responses. They discovered that deceptive responses were slower than truthful ones, with an average delay of 58 milliseconds in RTs. Furthermore, deceptive responses exhibited an increased activity in the medial frontal negativities (MFN), reflecting heightened activity in the anterior cingulate cortex (ACC), a brain region implicated in resolving conflicts in response tendencies. This greater ACC activity during deception suggests the presence of conflicting response information during lying and the engagement of executive control processes in deceptive behavior.

1.3 Executive processes and brain areas involved in lying

As stated in the previous section, executive functions are found throughout the *Activation-Decision-Construction-Action Theory* (ADCAT) (Walczyk et al., 2003), but more specifically, which executive processes account for the lengthening of reaction times when answering in a deceptive way?

Lying entails the engagement of several executive control processes, encompassing directed attention, strategic planning, metacognition, manipulation of pertinent information within conscious working memory, inhibition of a prepotent response and activation of appropriate ones (Gombos, 2006). Spence et al. (2001; 2004) hypotized that deception requires three main aspects of executive control, to the extent that deception involves (1) the inhibition of a truthful prepotent response (referred to as *inhibitory control*, serving as an essential mechanism for withholding veracious information), (2) the retention of factual verity within cognitive awareness while concurrently devising a novel deceptive response (relying on the capacity of *working memory*), (3) the transitions between truthful and deceptive responses (encompassing *task-switching* and *cognitive updating*), (4) the constant monitoring of both the responses of the lie target and one's own within the contextual dynamics of the interaction (linked to the concept of *theory of mind*), and (5) the activation of neural structures within the central nervous system implicated in the orchestration of executive processes.

Hence, the act of responding with a lie entails an additional layer of cognitive processing that intricately engages executive neural systems, but specifically which brain areas are involved in lying?

Spence et al (2001; 2004) demonstrated that deception is associated with heightened activation in the bilateral ventrolateral prefrontal cortex, likely attributed to the inhibition of prepotent truthful responses and/or lie generation. Additionally, increased activation was observed in the anterior cingulate cortices, coupled with the medial premotor regions, the left inferior parietal cortices, and the bilateral Brodmann area 47. The latter area, as determined by lesion studies, has been established to be involved in processes such as perseveration, inhibition of prepotent responses, and conditional learning.

Langleben et al. (2002) employed *functional magnetic resonance imaging* (fMRI) contrasts between deceptive and truthful responses in a cohort of 18 participants engaged in the *Guilty Knowledge Test* (GKT) [1]. Their investigation revealed an enhanced neural activity pattern encompassing the anterior cingulate cortex (ACC), the superior frontal gyrus (SFG), and the left premotor, motor, and anterior parietal cortex, which was specifically associated with the execution of deceptive responses. Conversely, no distinct brain regions exhibited heightened activity during truth-telling in comparison to deception, implying that truth represents the fundamental cognitive baseline. According to the authors the inhibition of truthful responses serves as a foundational prerequisite for deliberate deception and while performing GKT the ACC activation is suggested to reflect the continual monitoring of conflicting responses (truth versus deception) and the inhibition of a prepotent basic response.

The continual monitoring of conflicting response tendencies when lying has been demonstrated also trough as liars' mouse trajectories exhibit a curvature towards a competing truthful response label and are slower and more erratic (Duran et al., 2010). Similarly, Hadar et al. (2012) demonstrated that prior to a deceptive response, motor-evoked potentials (MEPs) in the primary motor cortex associated with the fingers corresponding to the truthful response (the one that needs to be

[1] The *Guilty Knowledge Test (GKT)* is a forensic psychophysiological technique used in criminal investigations and polygraph testing to determine if a person possesses knowledge about a crime that only the perpetrator would likely have. Also known as the *Concealed Information Test* (CIT), it is based on the assumption that a guilty individual will react differently when presented with specific details or information related to the crime, compared to an innocent person who would not have such knowledge. (source: Lykken, D. T. (1959). The GSR in the detection of guilt. *Journal of Applied Psychology*, *43*(6), 385. https:// https://doi.org/10.1037/h0046060.)

inhibited) are greater than those associated with the fingers corresponding to the deceptive response (the one that needs to be provided).

Employing a paradigm akin to that utilized by Langleben and colleagues (2002), Phan et al. (2005) investigated the neural substrates of deception. The authors implemented a novel real-time f-RMI technology in order to simulate a polygraph experience while participants performed a modified version of GKT. Their findings support prior results of f-RMI studies of deception, revealing a distinct correlation between deceptive responses and the activation of the ventrolateral prefrontal cortex (VLPFC), dorsolateral prefrontal cortex (DLPFC), dorsomedial prefrontal cortex (DMPFC), and the right superior temporal sulcus. These findings provide support to the notion that activation within prefrontal cortical regions plays a crucial role in either the formulation of deceit, the inhibition of truth, or both processes.

In their study Christ et al. (2009) systematically examined the extent to which various dimensions of executive control, encompassing *working memory, inhibitory control*, and *task switching*, contribute to the phenomenon of deception. They employed an *activation likelihood estimate* (ALE) meta-analysis method, wherein the outcomes of the deception-related ALE analysis were compared against ALE maps individually generated for each of the abovementioned facets of executive control. They found that eight of the thirteen brain regions identified as showing deception related activity across studies were pinpointed within or proximate to the prefrontal cortex (PFC), suggesting the key role of executive processes in the domain of deception. Deceptive related regions significantly overlapped with regions underlying executive control, particularly in the bilateral insula, the left inferior frontal gyrus (IFG), the left middle frontal gyrus, the right intermediate frontal sulcus, the right anterior cingulate cortex (ACC), and the right intraparietal sulcus. Substantial overlap was evident across all three executive control maps in sections of the bilateral ventrolateral prefrontal cortex (VLPFC), the left ACC and the left posterior parietal cortex. Furthermore, a notable overlap between *working memory* and *inhibitory control* ALE maps was observed in the right ACC. Overall, the *working memory* ALE map was more extensive than the maps associated with either of the other two investigated executive functions.

Deception related regions in dorsolateral prefrontal cortex and posterior parietal cortex were associated with *working memory* but not *with inhibitory control* or *task switching*. Conversely, rostral sections of the bilateral ACC displayed unique associations with *inhibitory control* in contrast to *working memory* and *task switching*. Finally, a specific region within the left occipital cortex was linked to *task switching* but not to *working memory* or *inhibitory control*.

These neuroscience findings support the idea that lie production may be more cognitively demanding than truth telling because of a greater need for executive processing. Furthermore, scientific research on the development of lying ability in children has demonstrated that it develops alongside the ongoing development of executive functioning, especially inhibition (Carlson et al., 1998).

Besides the findings deriving from neuroscientific research many sources support the premise that lying is cognitively demanding. Further substantiation of the increased cognitive burden associated with deception emerges from the study conducted by Vrij and colleagues (1996). In this research, participants engaged in a mock crime scenario were asked to rate the cognitive load experienced during their interviews. Notably, they reported that fabricating a lie imposed greater cognitive strain compared to truth-telling. Building upon these findings, Vrij et al. (2010) investigated the subjective experience of individuals who engaged in deception using diary reports. Participants were instructed to meticulously document all their social interactions over a week, including all lies they told in these interactions. The outcomes indicated that individuals who lied reported a higher cognitive demand during deceitful interactions compared to truthful interactions. Furthermore, a positive correlation emerged between the perceived gravity of a lie and the cognitive load it imposed. Mann and Vrij (2006) demonstrated that police officers, upon viewing videotapes of suspect interviews, reported that individuals in the lying condition *"seemed to think more laboriously"* (i.e., increased cognitive load) and seemed to try to control their behavior more than when they were telling the truth. Given the cognitive demands of lying relative to truth-telling, the scrutiny of cues indicating cognitive load appears promising in distinguishing between deceivers and truth-tellers. Regrettably, however, this discriminative capability is not consistently realized.

1.4 Lying is not always a difficult task: the exception of prepared or rehearsed lies

If lying is cognitively demanding, then attending to cognitive load signs will in turn help to discriminate between lying and telling the truth? An answer to this question was given in 2003 with the publication of two explanatory meta-analyses that demonstrated the subtle and inconsistent nature of nonverbal and verbal cues to deception in normal conditions.

In Zuckerman and colleagues (2003) meta-analysis verbal and non-verbal cues to deception, directly resulting from cognitive processing, were assessed. They found that lying was associated with only two indicators of complex cognitive processing, such as an increase in pupil dilatation and in speech hesitations. Interestingly, observers were more inclined to perceive communications as deceptive when they were characterized by lengthier response times (RTs), decreased speech rate, greater speech errors, and more frequent hesitations during speech.

DePaulo et al.'s meta analysis (2003) encompassed a comprehensive examination of 50 verbal and nonverbal cues across nearly five dozen deception studies. Out of these 50 cues, merely 14 (28%) exhibited significant associations with deception, and their average *effect size* was small. Specifically, the authors found that liars tended to display more dilated pupils and were frequently prone to speech disturbances such as altering sentences, employing filled pauses, and employing silent pauses. Notably, neither of the aforementioned meta-analyses captured RTs as a reliable indicator to discriminate between deceptive and truthful accounts. Thus, the question arises: What accounts for the results observed in these meta-analyses?

First, not all lies require equal cognitive resources. Previous Vrij & Haeven (1999) findings revealed that lie cognitive complexity (i.e., lies difficult to fabricate vs.

easy to fabricate) exerts an influence on the occurrence of cues to deceit, and therefore depending on the cognitive load required by lie production greater or weaker cue to deceit will arise. Secondarily, due to the variable nature of lying as a skill across individuals, proficient deceivers, commonly referred to as *good liars*, may exhibit a reduced number of cues to deceit. *Good liars* possess typical characteristics that complicate lie detection, including perceiving the act of lying as cognitively undemanding and the adeptness to mask signs of cognitive load (Vrij et al., 2010). Then there is yet another reason why it is difficult to discriminate between a lie and a truth, and it refers to the *Othello error (*Bond & Fahey, 1987; Ofshe & Leo, 1996) a common mistake that leads to misinterpret signs of emotional arousal, nervousness or cognitive load as indicators of lying. We are led to think that signs of nervousness and cognitive load are displayed only by liars, conversely these signs can also occur in truth-tellers, especially if they are aware that they are scrutinized and/or are afraid of not being believed.

A further possible explanation may be found in the fact that different strategies are implemented by liars and truth-tellers when answering interview questions to determine the veracity of their statements. In their study, Hartwig and colleagues (2007) investigated the distinct strategies adopted by both deceivers and truth-tellers during interrogations to substantiate their veracity. Their findings revealed that liars tended to utilize strategies before the interrogation to appear credible to a larger extent than truth-tellers. Conversely, truth-tellers most commonly employed strategy was to "*tell the truth like it had happened"*, reflecting the underlying belief that *"if one is innocent, there is little need to tailor the story to make it sound credible*". Such common credence is rooted in the *Illusion of transparency* (Gilovich et al., 1998), according to which *"the innocence shows on the outside and the truth will come out"*. Truth-tellers chose not to employ explicit strategies, thus when answering investigative questions only must recall what they truly experienced, relying on their memory. By contrast liars often prepare a *lie script* (Clemens et al., 2011) to answer questions they are likely to be asked to reduce their cognitive load during the interview, if those questions do arise, they can, like truth-tellers, rely on their memory instead of having to make up a convincing story on the spot.

A further interesting result of DePaulo et al.'s (2003) meta-analysis, supporting the fact of liars preparing in advance their deceptive accounts to reduce their cognitive load, is that they made fewer spontaneous corrections while telling their stories and stuck closely to the key elements of the story they were fabricating providing fewer unusual details (DePaulo et al., 2003). Additionally, Leins et al. (2013) found that when given the freedom to choose the content of their reports, liars choose events that they experienced, rather than fabricating on the spot their reports based on imagined events that were never experienced. Thus, liars avoid constructing their accounts using general or conceptual knowledge, rather they fabricate them using event details retrieved from their autobiographical memory making their task easier by reducing the cognitive burden associated with lying.

Moreover, it has been found that also pairs of liars prepare themselves for a possible investigative interview. Pair of liars know the importance of avoiding contradicting each other to prevent the interviewer from having doubts about their veracity and that's probably why a high consistency is found among their statements when compared with the consistency of truth-tellers' statements (Granhag et al., 2003).

In conclusion, lying may not be such a complex cognitive task, as well as response RTs and statements' consistency may not be reliable indicators to discriminate between lies and truths, since liars can effectively decrease their cognitive load by preparing themselves for the interview contemplating which questions will come up an anticipating possible alternative answers (Clemens et al., 2011).

Interestingly, both aforementioned meta-analyses made a distinction between planned and unplanned lies, considering planning as a moderator factor, which aids in clarifying the relationship between lying and cues to deceit in general and reaction times (RTs) more specifically.

In Zuckerman and colleagues (2003) meta-analysis liars were categorized based on the level of planning invested in their lies (i.e., low, medium or high). The authors found that highly planned lies were associated with shorter RTs, whereas unplanned or inadequately planned lies exhibited longer RTs compared to truthful accounts. Likewise, DePaulo et al.'s meta-analysis (2003) distinguished between unplanned and planned presentations. When respondents did not pre-plan their answer there was a greater latency between the end of the question and the beginning of the answer. In contrast, when respondents premeditated their answers the response latency dropped until it became even shorter than when conveying the truth. Similarly, Walczyk et al. (2009; 2012) observed that participants who had time to prepare and practice their deceptive responses exhibited reduced RTs compared to those who provided unprepared or unrehearsed deceptive accounts during a cognitive lie detection test.

These outcomes are aligned with Littlepage & Pineault findings (1985), which showed that detectors are less accurate in identifying planned lies compared to spontaneous lies, indicating that planning increases the effectiveness of lies by providing the opportunity to develop a plausible verbal response and inhibiting nonverbal cues to deceit.

Another pertinent study by Van Bockstaele et al. (2012) explored the impact of practice in lying or truth-telling on the cognitive cost of lying. By manipulating the proportion of lie and truth trials in a *Sheffield lie test* (SLT) [2] (Suchotzki et al., 2018), the authors demonstrated that lying became easier for participants in the frequent-lie group (75% lie, 25% truth), while it became more difficult for participants in the frequent-truth group (25% lie, 75% truth). In other words, the more questions participants lied about the easier it was to lie. Additionally, Hu et al. (2012) demonstrated that individuals can be trained to be more proficient in the controlled processes associated with deception, such as *conflict monitoring* and *response inhibition*. The authors asked each participant to perform twice a *Differentiation of Deception Paradigm* task (DoD) [3] (Fuerdy et al., 1988) using self

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[2] The *Sheffield lie test* (SLT) has been frequently used in laboratory research investigating basic mechanisms of deception. This test effectively discriminates between individuals who engage in deception and those who convey truthful information by assessing their response times and error rates when responding to interrogative stimuli. (source: Suchotzki, K., Berlijn, A., Donath, M., & Gamer, M. (2018). Testing the applied potential of the Sheffield Lie Test. Acta Psychologica, 191, 281-288.)

[3] The *differentiation of deception* (DoD) paradigm a model employed in investigations concerning deception detection within forensic psychology. It aims to differentiate physiological responses (e.g., heart rate, blood pressure, skin conductance) and behavioral patterns (e.g., reaction times) associated with deception (test phase) from those associated with truth (baseline). (source: Fuerdy, J.J., Davis, C., Gurevich, M. Differentiation of Deception as a Psychological Process: A Psychophysiological Approach. *Psychophysiology, 25*(6), 683-688. https://doi.org/10.1111/j.1469-8986.1988.tb01908.x)

and other-referential information. In the truthful block, participants were asked to respond to all stimuli honestly by pressing the key indicating "*self*" to their self-referential information and the key indicating "*other*" to the other-referential information. By contrast, in the deceptive block participants were asked to press "*self*" to the other-referential information and to press "*other*" to their own information (i.e., to pretend they were someone else while concealing their identity). The results indicate that the performance associated with deception can be voluntarily controlled, as instruction given to speed up responses alone significantly reduced the RTs associated with participants' deceptive responses. However, the differences in RTs between deceptive and truthful responses were erased only in the training group, in which participants were not only instructed on how to speed up responses but were also required to perform additional trials involving deceptive responses.

Consequently, these studies collectively underscore the adaptability of deception-related performance and its potential for voluntary control, as even relatively little practice is enough to alter the cognitive cost of lying.

As researchers have already proven, different patterns of brain activation arise when individuals engage in deception compared to when they tell the truth (Christ et al., 2009; Phan et al., 2005; Spence et al., 2001; 2004). However, the brain activation's pattern varies also between memorized-rehearsed and unmemorized-unrehearsed lies. Ganis et al. (2003) demonstrated that when a unmemorized-unrehearsed lie is told a number of brain regions are activated more strongly than when a memorized lie is produced, including the anterior cingulate, extending into the left premotor cortex, the left precentral gyrus, the right precentral and postcentral gyrus, and the right cuneus, which are all brain areas involved in semantic and episodic memory, visual imagery, working memory load, conflict monitoring and inhibition of competing responses. In contrast, during the production of memorized-rehearsed lies, only the right anterior middle frontal gyrus, implicated in episodic retrieval operations, exhibits heightened activation.

In conclusion, synthesizing the reviewed literature evidence allows the argument that pre-planning and rehearsal make lying easier and that planned-rehearsed lies typically exhibit fewer cues to deceit than do spontaneous lies, rendering them more challenging to detect. Translated to the forensic context these scientific findings allow a reflection on the effectiveness of *Cognitive Load Approaches* (CLAs) (Blandòn-Gitlin et al., 2014; Masip & Herrero, 2015; Vrij et al., 2006; 2012; Walczyk et al., 2013) in lie detection and, more specifically, on the usefulness of the *unexpected questions technique* (Parkhouse & Ormerod, 2018) in unmasking lies. In fact, the positive effects of planning will emerge only if the liar correctly anticipates which questions will be asked. Given that unexpected questions are in no way predictable by the respondent, the latter has no possibility to train in lying and therefore cannot minimize lying's cognitive load, thus making the lie more easily unmasked through cognitive load signs.

1.5 Cognitive load approaches in lie detection (CLAs)

In the realm of lie detection research, empirical evidence has consistently demonstrated that humans exhibit a rather limited proficiency in distinguishing deception from truth (Bond & DePaulo, 2006). People's ability to detect deception by scrutinizing both verbal and nonverbal cues has yielded an average accuracy rate of approximately 54% in correctly distinguishing between lies and truths. Specifically, individuals have managed to accurately classify 47% of lies as deceptive and 61% of truths as non-deceptive. It is worth noting that this performance tends to improve when baseline behaviors are available, particularly in cases where lies are spontaneous and devoid of prior rehearsal. These findings logically align with the findings of DePaulo et al.'s (2003) comprehensive meta-analysis. This meta-analysis revealed that most verbal and nonverbal cues do not exhibit a discernible association with deception. Moreover, the cues that do display a connection with deception demonstrate a weak correlation. Consequently, the prevailing understanding in the field is that cues indicative of deceit are scarce, diagnostically unreliable, and inconsistently manifested (DePaulo et al., 2003).

In light of this recognition, a notable shift has occurred in the domain of deception detection research. Researchers have redirected their focus towards enhancing deception detection by intensifying cognitive demands on individuals, particularly on liars, with the specific goal of exacerbating cues indicative of deceit. To achieve this objective, contemporary research has placed emphasis on the development of *Cognitive Load Approaches* (CLAs) for deception detection (Blandón-Gitlin et al., 2014; Masip & Herrero, 2015; Vrij et al., 2006; 2012; Walczyk et al., 2013).

The fundamental premise underlying CLAs posits that lying is more cognitively demanding than truth telling. Consequently, if cognitive demands are further heightened through the strategic implementation of specific interview techniques designed to disproportionately burden liars relative to truth-tellers, a distinct advantage in detecting deception may be achieved. This approach raises the question: why do liars experience a more significant adverse impact?

Liars, whose cognitive resources are already partially depleted by the act of lying, are expected to find the additional concurrent task, as requested by the interview methodology, especially taxing. As more cognitive resources are requisitioned during deception, liars are left with fewer cognitive reserves. Consequently, if cognitive demand is further raised by making additional concurrent requests liars may reach a state of cognitive overload, potentially compromising their ability to cope with these additional requests. Consequently, liars may exhibit more discernible verbal and nonverbal cues to deceit (Diana et al., 2013). Truth-tellers likewise will undoubtedly experience an increased cognitive load (Parkhouse & Ormerod, 2018), nevertheless, unlike liars, this heightened cognitive load will not be substantial enough to result in a significant deterioration in their performance.

In sum, the proposal of enhancing cognitive load, as advocated by the *Cognitive Load Approach* (CLA), can lead to a heightened diagnostic value of verbal and nonverbal cues to deceit. This heightened manifestation of such indicators is particularly observable in individuals engaging in deception, as their cognitive resources are already partially depleted due to the act of lying. Liars' increased cognitive load will reflect itself in his verbal and nonverbal behavior, thus eliciting the most differential responses between truth-tellers and liars that are diagnostic of deception and therefore increasing the ability to detect deception by attending to signs of cognitive load (Masip & Herrero, 2015, Parkhouse & Ormerod, 2018).

However, which are the main interview methods employed within *Cognitive Load Approaches* (CLAs) that impose greater cognitive demands compared to control conditions? One frequently utilized technique in investigative interviews to heighten cognitive load is the *reverse order technique* (Vrij et al., 2008; 2012). This technique necessitates the recounting of an event in reverse chronological order, effectively preventing the reconstruction of the event from a pre-established schema and deviating from the conventional forward order encoding sequences of an event. When recalling events in reverse order the best cognitive strategy is to initially think of the event in forward sequence and then mentally reverse the steps. It is evident that response times are slower in backward recall compared to forward recall (Thomas et al., 2003). Backward recall is expected to have a more detrimental impact on liars than on truth-tellers, this is because their imagined and invented account would be challenging to manipulate during backward recall, if compared with the manipulation of a really experienced event as is the case of truth-tellers.

In a study conducted by Vrij et al. (2008), mock suspects either told the truth or lied about an event, either asked or not asked to report the event in reverse order. The results of this study demonstrated that interviews employing the *reverse order technique* yielded significantly more cues indicative of deception than control interviews. In the second part of the same experiment, police officers were asked to make veracity judgments based on videotaped interviews. Their judgments were notably more accurate when the interviews were conducted using the *reverse order technique*. In a subsequent study by Vrij et al. (2012), these findings were replicated. Participants, in this case, either truthfully reported or lied about a route they had taken. The results reaffirmed that responses provided in reverse order contained more cues to deceit, such as fewer details and more contradictions, compared to responses given in chronological order. Furthermore, observers exhibited greater accuracy in their veracity judgments when respondents described their routes in reverse order, thus demonstrating the facilitating effect of the reverse order technique on lie detection.

Another instructional method that interviewers can employ to increase interviewees' cognitive load involves instructing them to maintain fixed eye gaze on the interviewer (Vrij et al., 2010). *Gaze aversion* (GA) has been shown to play a role in managing the cognitive load implicated in the processing of environmental information. When individuals are posed with moderately challenging questions, they often avert their gaze to a motionless point in order to disengage from environmental stimulation. This occurs because maintaining eye contact constitutes a distracting task. Consequently, through *gaze aversion*, the efficiency of cognitive processing is enhanced (Glenberg et al., 1998). Moreover, further evidence has demonstrated that *gaze aversion* is a functional behavior, as it promotes learning and enhances performance (Glenberg et al., 1998; Phelps et al., 2006). Additionally, the more cognitive engagement a question demands, the more pronounced *gaze aversion* tends to be (Doherty-Sneddon & Phelps, 2005). In their study, Vrij and colleagues (2010) found that mock suspects instructed to maintain eye contact with the interviewer exhibited more cues to deceit compared to participants in the control condition. Subsequently, recorded interviews were presented to undergraduate students who were tasked with making veracity judgments based solely on the audio of the interview or on both the video and audio. The results revealed that keeping the eye gaze fixed on the interviewer improved the student's ability to detect deception through emphasizing cues to deceit.

Another frequently employed paradigm to enhance liars' cognitive load consists in asking respondents to perform an additional task while answering interview questions (Lancaster et al., 2013; Gawrylowicz et al., 2016; Goto & Hakoda, 2020). In such a cases, the *dual-task effect* comes into play, referring to the interference individuals experience when simultaneously engaged in two tasks (Pashler, 1994). Liars are expected to find the second task particularly taxing, given that they are already engaged in the inherently challenging act of lying, which should result in a more prominent display of cues to deceit.

For instance, Lancaster et al. (2013) asked participants to engage in a sorting task, which required them to allocate differently shaped objects into different containers while being interviewed about some activities they had supposedly carried out. Participants in the truthful condition had truly completed the activities, whereas deceptive individuals merely observed the room where the activities took place. Liars, compared to truth-tellers, sorted significantly fewer objects per minute and their answers showed a more pronounced decline in the amount of details provided. Similarly, Goto & Hakoda (2020) explored the impact of cognitive load induced by lying on word recall. Liars remembered fewer words than truth-tellers, indicating that the cognitive load elicited by lying depleted the cognitive attentional resources needed for subsequent word recall. Gawrylowicz et al. (2016) used a drive simulator as a cognitive load inducing technique to enhance differences in liars and truth-tellers during an investigative interview. In all three veracity conditions (truth, rehearsed lies and unrehearsed lies), participants exhibited slower reaction times during the dual-task scenario than during baseline, suggesting that the drive simulator task effectively increased cognitive load. Additionally, truth-tellers provided significantly more visual and auditory details, mentioned significantly fewer cognitive operations than liars and had significantly faster reaction times, than both rehearsed and unrehearsed liars. These findings demonstrate that dual-task paradigms can be successfully implemented to manipulate cognitive load in liars and intensify performance disparities between liars and truth-tellers.

Subsequently, some scholars have devised specific interview protocols aimed at effectively distinguishing between false and truthful statements by manipulating the cognitive load of respondents. One widely employed technique is the *Strategic Use of Evidence (SUE) technique*, as described by Granhag & Hartwig (2014). The rationale underlying this technique is that the consistency between the available evidence and the narrative provided by the suspect serves as an indicator of truthfulness and, to enhance liars' contradictions, the evidence countering their false accounts is deliberately withheld until the conclusion of the interview. The fundamental principles underpinning the SUE technique are as follows: (1) The suspect forms an hypothesis on the evidence held by the interviewer, (2) this hypothesis influences the suspect's choice of counter-interrogation strategies, (3) the suspect's choice is reflected in their verbal behavior during the four-step interview. Guilty and innocent suspects employ different counter-interrogation strategies in their attempts to persuade the interviewer of their innocence. Liars, who often premeditate various strategies to avoid detection, tend to employ an avoidance strategy during the interview. This strategy involves refraining from disclosing critical information that might prove their guilt during the interview, and if deprived of the avoidance option they may turn to escape responses, such as outright denial. In contrast, truth-tellers are less inclined to employ avoidance and escape strategies. They believe that by being forthcoming, they will be perceived as truthful. The aim of the SUE technique is to strategically introduce the available incriminating evidence during the interview, thereby altering the suspect's perception of the evidence and exploiting the differences in strategies and verbal behavior between liars and truth-tellers. When suspects overestimate the extent of information the interviewer holds, they run the risk of voluntarily disclosing incriminating information previously unknown to the investigators. On the other hand, if they underestimate the amount of information held by the interviewer, they risk being confronted with inconsistencies between their statements and the evidence. In a study conducted by Hartwig et al. (2006), police officers were either trained or not trained in the SUE technique. The findings indicated that liars who were interviewed by trained interviewers exhibited more inconsistencies between their statements and the evidence compared to liars interviewed by untrained interviewers. Additionally, trained interviewers achieved a significantly higher detection accuracy (85.4%) than untrained interviewers (56.1%).

Another interview procedure employed for the purpose of detecting deception is the *Time Restricted Integrity-Confirmation* (TRI-Con) method, as developed by Walczyk and colleagues (2009; 2012). The TRI-Con method is grounded in the premise that lying demands greater cognitive effort than telling the truth. Therefore, it posits that the responses of liars will exhibit more inconsistency and require longer formulation times. The procedure encompasses three main components: (1) Initially, poses questions unrelated to the subject of the investigation, for which the respondent can only provide truthful answers. These questions serve to establish a *truth baseline* for the interviewee, (2) subsequently, the interviewee is advised that the upcoming questions will pertain to the investigation's topics for which the interview is being conducted. The rationale behind this step is to activate truthful information in the respondent's memory. This activation is advantageous for truth-tellers and disadvantageous for liars because the more truth is active, the greater the cognitive effort required to inhibit it. (3) Finally, specific questions are not disclosed until the last moment to prevent the liar from preparing premeditated responses in advance. To ensure more precise measurement of cognitive load, questions are formulated to elicit brief one- or two-word responses, which should be provided as quickly as possible.

In an experiment conducted by Walczyk et al. (2009) utilizing the TRI-Con method, participants were required to respond truthfully or falsely to question concerning their personal data. The results demonstrated that lying subjects exhibited significantly longer response times and greater inconsistencies in their responses to related questions compared to truth-tellers. The findings revealed that TRI-Con was effective in distinguishing between truth-tellers and liars, with accuracy rates reaching 89%. Subsequently, Walczyk et al. (2012) conducted another experiment to maximize liars' cognitive load by combining TRI-Con method with the instruction to maintain eye contact with the examiner. For both yes–no questions and open-ended questions, unrehearsed liars took significantly longer to answer than both truth-tellers and rehearsed liars, indicating that rehearsal is an effective cognitive load-attenuating countermeasure, as evidenced by the reduction in response time. Additionally, a relevant outcome of the study was that truth-tellers exhibited significantly more eye movements than both rehearsed and unrehearsed liars. This suggests that liars, may intentionally reduce their eye movements to minimize environmental distractions and aid in recalling their preplanned lies.

An underutilized yet highly effective procedure within the field of *Lie Detection* involves increasing the cognitive load selectively on deceivers by leveraging the phenomenon of *switch cost* induced by *task switching*. *Task switching* is a crucial high-level cognitive ability that enables individuals to direct and allocate their attentional resources across multiple sequential cognitive tasks (Draheim, Hicks, Engle, 2016). In other words, it ensures the capacity to shift attention from one task to another.

In the context of typical deception paradigms *task switching* occurs even when transitioning from truth-telling to lying, or vice versa, such as when control and target questions are presented randomly. As a matter of fact, lying and truth telling can be considered as discrete cognitive undertakings (Foerster et al., 2016). The individual engaged in deceit is compelled to transition between these two cognitive tasks, thereby exerting an influence on task performance. This is the rationale behind the potential application of the *switch cost* as an indicator of deception, as proposed by Foerster et al. (2016). The presence of a performance *switch cost* is a well-established finding within the *task switching* literature. The *switch cost* manifests itself as participants being slower and more error-prone when switching tasks compared to when they repeat the same task (Kiesel et al., 2010; Monsell, 2003; Vandierendonck, et al., 2010). *Switch costs* reflects a residual effect, also known as *proactive interference* (PI), arising from the performance of a prior, competing task (Wylie & Allport; 2000). This residual effect of the previous task set simplifies performance when the same task is repeated over time, but when the task is alternated with another task, the previously performed task causes interference and must be inhibited (Allport et al., 1994; Koch et al., 2010).

It is noteworthy that as early as 1927, Jersild demonstrated that alternating between two distinct cognitive tasks, as opposed to consistently applying the same cognitive task to different stimuli, resulted in an increase in reaction times of approximately 0.5 milliseconds. Furthermore, when the alternating tasks were similar but opposing in nature (as in our case, telling the truth and lying), reaction times increased even further.

Consistent with these scientific findings, Sheridan & Flowers (2010) developed the *Timed Antagonistic Response Alethiometer* (TARA), which is a true-false statement classification task designed to detect deception by identifying slower average response times attributed to *task switching*. The base explanatory underlying TARA is that when lying two opposite strategies must be adopted, one for control statements (i.e., “if true indicate true and if false indicate false”) and one opposite strategy for target statements (i.e., “if true indicate false and if false indicate true”). The rationale behind TARA is found upon the notion that formulating a deliberately false response takes longer than generating a truthful one, as it necessitates prior knowledge of the truth followed by a strategic switch, thereby introducing an additional element into the response process. Additionally, liars, as opposed to truth-tellers, are compelled to alternate between these opposing strategies during successive trials, consequently amplifying the cognitive load due to *task switching*.

Debey et al., (2015) investigated the role of *task switching* in a deception context. The authors measured the *switch costs* associated with lying and truth telling using the *Sheffield lie test* (SLT) [4] (Suchotzki et al., 2018), which is a reaction time-based deception paradigm suitable for investigating *task switching*. Within this paradigm, participants are tasked with responding to simple yes/no questions by pressing a key. Simultaneously with the questions, the response labels ‘‘YES’’ and ‘‘NO’’ appear on the screen and their color instructs to lie or to tell the truth. The results demonstrated an increase in reaction times and the number of errors when transitioning from truth telling to lying and vice versa, with no differences observed between the two scenarios (from lying to truth telling or from truth telling to lying).

Monaro and Sartori (unpublished data) further demonstrated that *switch cost* alone is sufficient to elevate liars' cognitive load and increase response times associated with deception. The authors ran an experiment related to identity deception, measuring participants' reaction times to close-ended questions requiring a yes-or-no dichotomous answer. Half of the participants were instructed to memorize a false identity and provide deceptive responses regarding their personal information, while the other half were instructed to truthfully answer with their personal information. The identity-related questions consisted of simple statements such as "My name is Martina" or "I am a college student." Liars were expected to answer affirmatively when the statement matched the false identity they had memorized, while truth-tellers answered affirmatively when the statement aligned with their

[4] *Ivi, p.22.*

identity. However, both liars and truth-tellers were required to truthfully respond to control questions related to the current experimental situation, such as "I am taking part in an experiment" or "I'm sunbathing on a beach." Throughout the task, identity-related and control questions were randomly presented, resulting in liars continuously and unpredictably switching between questions that necessitated a truthful response (control questions) and questions that required a deceptive response (identity-related questions). The findings provided evidence supporting the effectiveness of *switch cost* in increasing liars' cognitive load. Specifically, *switch cost*, calculated as the difference in response times between identity-related and control questions, exhibited a significant correlation with the experimental condition.

Another widely used interview method in the field of *Cognitive Load Approaches* (CLAs) is the *unexpected question technique*. Due to the relevance and centrality it occupies in this dissertation, this technique will be discussed in a separate section below.

1.6 A possible solution: asking unanticipated questions

The rehearsal of a lie can be considered an effective countermeasure against lie detection load-inducing techniques (O'Hair et al., 1981; Greene et al., 1985). However, the cognitive load reduction strategy of preparing for the interview by anticipating possible questions and producing possible answers in advance works only if the liar correctly anticipates the questions to be asked and it becomes ineffective when the interviewer poses questions that the liar cannot foresee (Vrij, 2016).

Based on this premise, a specific interview method known as the *unexpected question technique*, has been implemented to improve lie detection accuracy. According to Sartori (2011), a question is unexpected when requires a reasoned response from a liar but elicits an automatic response from a truthful subject. Consequently, while the information required to answer an unexpected question is readily accessible and automatic for a truthful subject, the liar is compelled to engage in mental calculations to retrieve the necessary information and construct a response (Vrij et al., 2009). This technique effectively exploits differences in the cognitive load experienced by truth-tellers and liars, thereby increasing the lie detection accuracy by accentuating the differences in their verbal and nonverbal behavior (Vrij, 2014; Warmelink et al., 2012; Sooniste et al., 2016).

But why does it work? As liars have not prepared answers to unanticipated questions, they cannot rely on the *lie script* (Clemens et al., 2011) they usually prepare before the interview. Consequently, they are forced to generate in a short time span new details, which were not part of their original prepared script. When confronted with unexpected questions, liars must invent on the spot an answer, inhibit the true response and substitute it with the lie, and finally mentally verify that the lie is not easily detectable by the interlocutor. These complex mental operations required of liars, stemming from the information reconstruction process triggered by unexpected questions, result in a higher cognitive load. This heightened cognitive load leads to longer response times and reduced response accuracy, rendering slowness and inaccuracy in answering unexpected questions as diagnostic indicators of lying (Parkhouse et al., 2018). It is worth noting that a liar may also refuse to answer an unexpected question by claiming ignorance or memory lapses. However, liars understand that such answers will generate suspicion in the interlocutor, especially if the question pertains to central aspects of the interview's target topic. Thus, the liar's primary alternative is to fabricate a plausible answer on the spot. In contrast, truth-tellers experience relative similar levels of cognitive load when answering to expected and unexpected questions because they can draw upon real memories of events, resulting in more comparable answers to these two kinds of questions (Vrij, 2014).

Examples of unexpected questions used in experimental settings include inquiries about the planning phase of future behavioral intentions (Sooniste et al., 2015; 2016), questions regarding spatial and temporal details and shifts (Lancaster et al., 2013; Vrij et al., 2009; Leins et al., 2011), queries about transportation (Warmelink et al., 2012), questions concerning the occurrence mental images that participants may have had during their planning of a mock criminal event (Knieps et al., 2013) and questions about personal information that can be derived from participants' identity cards (real or fake), such as "*What is your zodiac sign?*" (Monaro et al., 2021).

To effectively discriminate between liars and truthtellers, it is essential to compare their responses to unexpected questions with those given to control and expected questions (Sartori, 2021). Control questions pertain to the specific circumstances of the ongoing experiment or the subject's directly verifiable physical characteristics. Examples of control questions include, "*Are you in front of a computer right now?*" or "*Do you have blond hair?*" or "*What is your gender?*". These questions are ones that even liars cannot deceive since the truthfulness of the answer can be directly verified by the interviewer. Analyzing the response latency to these questions allows for the calculation of the average time it takes for an individual to respond truthfully to a question. Through the support of control questions, it is possible to use the answer we know with certainty to be true in order to compare it to the answer whose truthfulness must be verified. This practice, called *baselining method*, is recommended to be implemented in investigative interviews in order to increase their diagnostic accuracy (Vrij, 2016; Palena et al., 2018; Verigin et al., 2021). It is important to specify, however, that for the *baselining method* to be effective, when comparing a person's deceptive verbal or nonverbal responses with their truthful responses, they must be obtained from the same interview. Additionally, the respondent should discuss similar topics in both the deceptive and truthful segments, and these segments should occur within a short timeframe of each other. In this regard, Vrij (2008) mentions the concept of a *"comparable truth baseline"*. On the other hand, expected questions are by definition predictable questions, since they concern the main topic on which the interview is about and whose truthfulness has to be ascertained. There is no way to evaluate the genuineness of the answer given to these questions, so interviewees are allowed to lie. Liars anticipate these kinds of questions and prepare their answers in advance, that preparation being what makes their answers and those given by truth-tellers more comparable. As a result, response times to these questions are a less reliable indicator for discriminating between truthful and deceptive answers (DePaulo et al., 2003; Zuckerman et al., 2003).

The central role in this procedure is played by unexpected questions—those questions that the respondent does not anticipate and, therefore, cannot prepare for in advance (Sartori, 2021). These questions can be considered as a *rehearsal averting strategy*, and the lengthening of response times by liars to these questions represents one of the most effective diagnostic indicators of deception (Monaro et al., 2021). Once the response times are obtained (with precise measurement down to the millisecond using software like Audacity [5], the average latencies to control, expected, and unexpected questions are computed for each subject. Liars exhibit a prototypical pattern of response times. Specifically, their response times are significantly longer than those of truth-tellers for unexpected questions (Monaro et al., 2021).

Although response times are a highly reliable indicator of cognitive load (De Boeck & Jeon, 2019; Stojmenova & Sodnik, 2018), and effectively capture the cognitive overload experienced by liars when confronted with unexpected questions, most studies employing the unexpected question method have nonetheless focused on identifying indicators other than response times, such as the degree of concordance between statements provided by pairs of suspects (Vrij et al., 2009; Sooniste et al., 2016), the degree of concordance in answers to the same unexpected question asked twice in a different format (Leins et al., 2011), the detailedness of accounts (Lancaster et al., 2013; Warmelink et al., 2012), and the availability of references to the planning phase of a future activity (Sooniste et al., 2015; 2016).

For example, Vrij et al. (2009) applied *the unanticipated question technique* to pairs of liars and truth-tellers who either pretended to have had lunch together or had done so. In this experiment, pairs of suspects were separately asked unexpected questions about spatial and temporal details, such as, for instance, "*In relation to*

[5] *Audacity* is a free and open-source digital audio editor and recording application software, available for Windows, macOS, Linux, and other Unix-like operating systems. In addition to recording audio from multiple sources, Audacity can be used for post-processing of all types of audios, including effects such as normalization, trimming, and fading in and out. (source: https://en.wikipedia.org/wiki/Audacity_(audio_editor))

where you sat, where were the closest diners?" and "*Who finished their food first, you or your friend?*". Subsequently, they were asked to separately sketch the layout of the restaurant. The researchers measured the correspondence between the answers of each pair of suspects and the consistency between their drawings. The results of their study demonstrated the effectiveness of asking unanticipated questions to unmask pair of liars. They found that the drawings of pairs of liars matched less than the drawings of pairs of truth-tellers. By examining the overlap in the drawings provided by the two members of each pair, it was possible to correctly classify 80% of both liars and truth-tellers. This represented a significant improvement over the conventional practice of using expected questions, which led to the correct classification of slightly over 50% of liars and truth-tellers.

The *unexpected questions technique* can also be applied for detecting deception in single subjects, as demonstrated by Lancaster et al. (2013). In their study, the authors instructed liars to generate a false story in which they claimed to have performed a task (the same task performed by subjects in the truth condition). Subsequently, pairs of expected and unexpected questions were posed to participants. When faced with unexpected questions involving temporal or spatial perspective shifts, liars provided less detailed responses compared to truth-tellers.

Warmelink and colleagues (2012) applied the *unexpected question technique* to detect lies about future intentions. In their study participants were asked to answer both anticipated and unanticipated questions (either truthfully or deceptively) concerning an upcoming trip they intended to make. Their findings showed that liars provided more detailed answers to expected general questions and less detailed answers to unexpected questions regarding transportation when compared to truth-tellers. Subsequent studies have corroborated the efficiency of the unexpected question concerning the planning phase of a task in discriminating between true and false intentions in both single subjects and small groups of subjects (Sooniste et al., 2015; Sooniste et al., 2016).

Particularly Sooniste and colleagues (2015) made a further distinction between truthful and lying response patterns to unexpected questions. Participants were asked to plan a mock crime or non-criminal event and then underwent an interview that included expected questions about their future intentions (e.g., *"I want you to tell me what you intend to do in this office building. Please tell me about each and every step – and try to be as detailed as possible"*) and unexpected questions concerning the planning phase of their previously stated future intentions (e.g., *"Now, I want you to think back to when you planned your goal, I want you to tell me about your planning, and I want you to be as detailed as possible"*). The level of detailedness of participants' responses was assessed on a 7-point *Likert scale* and results indicated that the truth-tellers' answers to the unanticipated questions were significantly more detailed compared to liars' responses. The authors subsequently conducted a similar experiment with dyadic and four-person groups, demonstrating that liars' answers were less detailed and that the reports of cells of truth-tellers achieved greater within-group consistency for questions about the planning phase (Sooniste et al., 2016). Additionally, truth-tellers' accounts about their future intentions contained more information regarding how to achieve the pre-posed goal known as *implementation intentions*, while liars provided more information about why it was necessary to achieve the pre-posed goal. Liars were not concerned, and therefore did not anticipate questions about how to attain the goal that they stated in the interview because it was a false intention, which only served the purpose to mask their real intentions.

Leins et al. (2011) assessed whether the degree of consistency in liars' and truth-tellers' responses across different reporting modes, such as sketches and verbal answers to spatial and temporal unexpected questions could serve as an indicator for detecting deception. The authors deliberately induced changes in the reporting mode of participants (e.g., verbally and pictorially), preventing liars from using strategies (e.g., repetition) in order to appear honest to the interviewer. Their results indicated that liars tended to be less consistent than truth-tellers across repeated interviews conducted with different reporting modes. But why is this the case? When confronted with spatial and temporal unexpected questions, liars must fabricate answers on the spot, and the memory trace of these fabricated answers may be more unstable than a truth teller's memory of a truly experienced event. Consequently, liars may contradict themselves more frequently than truth-tellers when the same question is presented in different formats across repeated interviews. In contrast, truth-tellers encode the topic of investigation along more dimensions than liars, and thus they should be capable of recalling the event more along more dimensions than liars (Vrij et al., 2011).

The effectiveness of unanticipated questions technique has been assessed in a meta-analysis by Vrij and colleagues (2015). The meta-analysis revealed that accuracy in distinguishing truth from deception reached 71% across various studies when unanticipated questions were employed, in contrast to the 56% accuracy achieved using standard interview methods. Another advantage of *the unexpected question technique* is its resistance to countermeasures, such as liars' attempts to mislead the investigator in order to be classified as truth-tellers, as the responses to unanticipated questions posed by the investigator cannot be preplanned by the liar (Vrij, 2011). Furthermore, the *unexpected questions technique* is a *within-subjects technique*, which is preferable since the answers to these questions vary among different respondents (Vrij, 2011).

CHAPTER 2: COUNTERFEIT IDENTITIES AND METHODS TO DETECT THEM

2.1 Identity deception

Deception is a ubiquitous phenomenon in real life interactions (DePaulo et al., 1996) but could the same be said for *identity deception*? To begin this investigation, it is crucial to clarify the concept of identity. Identity refers to the distinct characteristics that define an individual and set them apart from others (Donath, 2002). Nonetheless, identity is not a single-dimensional construct; instead, it comprises various sub-components, namely *biometric identity, biographical identity,* and *attributed identity* (Clarke, 1994). The principal sub-component among these is *attributed identity*, which encompasses the anagraphic information assigned to individuals at birth, including their first name, last name, date and place of birth. Consequently, it is often the primary means through which identity is established. *Biographical identity* encompasses personal information related to an individual's life history, such as their financial, criminal, and educational background. The final sub-component, *biometric identity*, includes the aspects of personal identity that are most challenging to falsify, as it encompasses biometric features unique to everyone, such as fingerprints and DNA characteristics. Among these three types of identity components, *attributed* and *biographical identities* are more susceptible to falsification due to their relative ease of modification.

Identity deception, as described by Wang et al. (2006), refers to a specific form of deception where individuals intentionally hide their original identity, assume the identity of someone else, or employ forged identity documents, thereby compromising the reliability of identity information due to deliberate deceit. The authors have identified three primary types of *identity deception*, *namely identity concealment, identity theft,* and *identity forgery* (Wang et al., 2006). *Identity concealment* occurs when certain aspects of one's identity are altered or withheld (DePaulo & Pfeifer, 1986). For instance, an individual may falsely claim to have been born on a different day, month, or year than their actual birthdate or may associate a fictitious first name with their genuine surname, or vice versa, by using a different last name with their real first name. Concealment is evidently a more advantageous strategy compared to employing a completely fabricated identity since individuals may find it easier to recall partially true information as opposed to a wholly fictional identity (Cohen, 2001).

Wang and collegues (2004) conducted a study to identify various patterns in which *identity concealment* occurs by comparing individual deceptive records, which included information such as name, date of birth, address, identification number, race, weight, and height, with genuine identity records. The deceptive records were classified into four categories: name deception, residency deception, date of birth (DOB) deception, and ID deception. Among the deceptive records, the majority (62.5%) had partially false names, while only 29.2% featured completely fabricated names (both first and last names falsified). Additional strategies for name forgery included changing the initial of one's middle name, shortening or adding letters to one's first name, using a name with a similar pronunciation to one's own, and swapping first and last names (Wang et al., 2004).

A real-world example that illustrates Wang and colleagues' (2004) findings is the tragic terrorist attack on the Twin Towers on September 11, 2001. The ringleader of the attack, Mohamed Atta, utilized eight different aliases, such as *"Mehan Atta," "Mohammad El Amir," "Muhammad Atta," "Mohamed El Sayed," "Mohamed Elsayed," "Muhammad Al Amir Awag Al Sayyid Atta,"* and *"Muhammad Al Amir Awad Al Sayad"* (Shen & Boongoen, 2008). It is noteworthy that these pseudonyms exhibited strong similarities to each other, as Atta did not completely alter his name by creating a completely fictitious one. Instead, his true first name or real last name were consistently present in all the aliases. Furthermore, in two instances, he used variations such *as "Mohammad"* and *"Muhammad"* instead of *"Mohamed",* thus providing a false name with a pronunciation similar to his real name.

Concerning date of birth deception, Wang et al. (2004) found that the majority of individuals only partially falsified it, altering only one element of the birthdate, such as the year, month, or day (e.g., changing 02/09/70 to 02/08/70). Similarly, in residency deception, only a portion of the complete address was modified. Thus, concealed identities often exhibit partial resemblance to the original identities. It could be hypothesized that individuals who engage in identity deception intentionally create false identities that are slightly different from their own real identities, likely to avoid excessive cognitive resource consumption (Cohen, 2001).

In a case study conducted by Wang et al. (2005) within a police department, it was discovered that approximately 30% of the suspects had employed a fraudulent identity. Among the various attributes, the name was the most frequently altered. The authors then expanded the range of strategies employed by individuals engaging in identity deception to create false names. These strategies encompassed the use of nicknames, the adoption of names translated from different languages, and the provision of someone else's name, such as that of a sibling (e.g., brother or sister).

Nowadays, the use of the internet exposes individuals to an increased risk of encountering *identity deception*. Device-mediated communication, which relies on textual messages and allows for visual anonymity, exposes individuals to a greater likelihood of encountering *identity deception* in online interactions. However, why do people lie online and to what extent? This question served as the title of a study conducted by Drurin et al. (2016). The study revealed that only a small percentage of participants (16%-32%) reported being or intending to be consistently honest across various websites, and an even smaller percentage (0.2%) suspected that others were always truthful on such websites. Walt et al. (2018) summarized findings from previous research and concluded that the most frequently falsified attributes online include image, name, location, ethnicity, age, gender, marital status, occupation, qualifications, and appearance - all characteristics that define and differentiate individuals from one another. Similarly, Utz (2005) found that the most common types of deception on the internet involve gender switching, identity concealment, and attractiveness deception. Therefore, we can assert that one of the most prevalent forms of deception on the internet is *identity concealment* (Caspi & Gorsky, 2006), wherein individuals send messages containing misleading information about their identity. Unfortunately, identity deception on the internet can also occur with malicious intent, as exemplified by the phenomenon of *child grooming*, which is refers to the process by which an adult gradually establishes a relationship with a child for the purpose of exploiting them sexually, emotionally, or for other illicit activities (Cano et al., 2014).

Two additional forms of *identity deception* encompass *identity theft* and *identity fraud*. *Identity theft*, also named *impersonation*, occurs when an existing person's identifying material is unlawfully obtained and used for fraudulent purposes, particularly, but not only, in the commission of financial crimes (Hatch et al., 2000). A clear example of *identity theft* is evident in the case where one of the terrorists involved in the Brussels airport suicide bombing on March 22, 2016, assumed the identity of a former Inter Milan football player (Agenzia Giornalistica Italiana, 2016).

Identity fraud, as defined by Koops and Leenes (2006) and Willox et al. (2004), involves the use of false identifiers, fraudulent documents, or a stolen identity (i.e., *identity theft*) in the commission of a crime. *Identity fraud* is a broader and more complex concept compared to *identity theft* because it encompasses the fraudulent use of any identity, whether real or fictitious, whereas *identity theft* specifically pertains to the theft of a person's real identity (Willox et al., 2004).

Identity liars pose a significant security concern at a national level, as terrorists and criminals often manage to cross national borders by evading airport security checks using forged documents. *Identity document fraud* is a criminal act involving the counterfeiting, forging, or theft of blank documents, typically with the intention of engaging in fraudulent activities (Baechler et al., 2012). In the past two decades, the Global Terrorism Database (GTD), which is maintained by the University of Maryland and widely regarded as the most comprehensive and reliable source of information on terrorism, has documented a total of 70,433 incidents of terrorism worldwide (Global Terrorism Database, National

Consortium for the Study of Terrorism and Responses to Terrorism). Analyzing the frequency of terrorist attacks since 1994, a notable trend of rapid growth can be observed, particularly starting from 2007 up to the present time. The Twin Towers bombing serves as a tragic illustration of *identity document fraud*, as the terrorists involved utilized fraudulent identification documents, including counterfeit driver's licenses, stolen credit cards, fictitious or temporary addresses, counterfeit passports, and fabricated social security numbers. This enabled them to cross national borders without detection (Willox et al., 2004). According to Frontex (2011), there was a 20 percent rise in the identification of false documents at Europe's external borders between 2009 and 2010, indicating a noticeable upward trend in the occurrence of this phenomenon.

The utilization of counterfeit identification has become a common factor across various types of criminal activities, including mafia trafficking, terrorism (Boongoen et al., 2010), human trafficking, drug trafficking, large-scale fraud, alien smuggling, weapons smuggling, and money laundering (Willox et al., 2004). Indeed, once a criminal or terrorist has created or obtained a false identity, they can exploit it to perpetrate economic crimes, engage in illegal drug trafficking, carry out terrorist attacks, and commit similar acts, all while evading detection of their real identity. All these crimes cannot be adequately understood without considering related activities, such as document forgery, which play a supportive role (Europol, 2002). According to the 2002 EU Organised Crime Report there have been notable advancements in computer and printer technology systems, enhancing the capabilities of organized crime groups to produce counterfeit documents of various kinds (Europol, 2002). These documents be easily obtained by accessing various Internet sites, engaging with corrupt officials, or accessing the underground market for counterfeit documents.

Effectively tracking and preventing criminal activities necessitates the authentic identification of offenders, who often possess multiple fraudulent names, dates of birth, addresses, bank accounts, telephone numbers, and email accounts (Boongoen et al., 2010). An airport security officer should know whether a passenger's documents, subjected to security checks, are genuine or counterfeit.

This knowledge is crucial in determining if the passenger is unlawfully crossing state borders with a malicious intent. These two steps rely on the accurate and precise assessment of the visual and physical characteristics of the passenger's document, whereby the usual practice is to compare its degree of congruence with official and authentic documents of the same sort. The problem arises when the airport security officers are unable to verify the authenticity of a document. In such cases, it becomes imperative to conduct a more comprehensive and sophisticated examination utilizing adequate human and technical resources.

As the results of the aforementioned articles show, false identities are becoming a widespread problem and the speed at which these deceptive identities evolve calls for solutions to detect identity deception.

2.2 Some new methods to detect fake identities

Personal identity information can be acquired and memorized to such an extent that identity deceivers can effortlessly and convincingly provide false biographical data as if they were true (Monaro et al., 2021). This is especially true when counterfeit identities closely resemble the real ones. Therefore, the unexpected question technique, which is a *rehearsal averting method* (Monaro et al., 2021), could prove to be an effective implementation strategy in contexts where determining the true ownership of an identity is crucial, such as airport screening services.

Professor Sartori, in his book "*The Memory of the Witness*" (2021) describes how he first experienced personally and directly the *unexpected question technique*. The author recounts an incident that occurred during a journey undertaken to participate in a neuropsychology conference hosted by Professor Moscovitch in Israel, precisely situated on Mount Carmel near Haifa, in close proximity to the Lebanese border. To facilitate the departure flight from Tel Aviv, Professor Moscovitch provided Professor Sartori with a letter of introduction to present at the airport to facilitate gate procedures. The letter stated that Professor Sartori was a professor from the University of Padua and had traveled to Israel to participate in the conference organized by Professor Moscovitch. Upon arrival at the Tel Aviv airport an airport security officer approached Professor Sartori and began to question him about his stay. The professor presented the letter and provided an explanation about the neuropsychology conference on Mount Carmel, the purpose of his visit to Israel. However, the security officer remained unsatisfied and proceeded to ask unexpected questions to verify the authenticity of Professor Sartori's claims.

According to Sartori (2011) an unexpected question is the one that *require a reasoned response in the case of the liar and, on the contrary, an automatic response in the case of the truth-teller*. Consequently, while the truth-teller can readily retrieve the information necessary to answer an unexpected question, the liar is compelled to engage in mental calculations to access the information and formulate a response. Liars may go to the extent of refusing to answer unanticipated questions, often claiming that they don't know or cannot remember the answer. Regrettably, such responses tend to raise suspicion in the interlocutor (Vrij et al., 2011).

The unexpected questions being asked on that occasion were basically two: the first one was "*When you went to Mount Carmel, leaving from Tel Aviv, did you turn first or after Haifa city?*" while the second question was "*Can you tell me what superficial dyslexia is?*". The first question was intended to verify the genuineness of the professor's statements regarding his attendance at the Mount Carmel conference. Questions related to explicit spatial and temporal details have been shown in international literature to be effective in eliciting cues to deception (Parkhouse & Ormerod, 2018; Vrij et al., 2009; Lancaster et al., 2013; Leins et al., 2011). Since the professor had actually traveled from Tel Aviv to Mount Carmel, he possessed a genuine memory trace that enabled him to answer the question accurately (Clemens et al., 2011). If he had not made the trip, he would have been unable to answer the question, raising suspicion among the airport security officers. The second question aimed to verify the authenticity of Professor Sartori's identity as an expert in the field of neuropsychology. Once again, the professor could easily provide an answer since his statement was genuine. However, if he were not truly an expert in neuropsychology and his statement was false, he would not have been able to answer the question.

In recent years, several scientific research studies have employed the *unexpected question technique* alongside other innovative methods, such as *kinematic analysis of mouse movements* and *keyboard dynamics* to detect *identity deception*. It is noteworthy to emphasize that these methods enable the detection of fabricated identities without any prior knowledge about the suspects' identity (Monaro et al., 2017). This capability distinguishes them from other alternative approaches used to detect fabricated identities, such as *autobiographical Implicit Association Test* (aIAT) [6] and *Reaction Times based Concealed Information Test* (RT-CIT) [7], which require the inclusion of identity information during the testing procedure (Marini et al., 2016; Verschuere & Kleinberg, 2016; 2017).

However, in many real-world scenarios, the examiner is unaware of the actual identity, rendering these alternative methods impractical. Indeed, both RT-CIT and aIAT are ineffective in scenarios where the crucial information to be assessed, such as the real identities of the respondents attempting to conceal their identity, are unavailable. Additionally, the measurement of mouse trajectory and typing patterns can be regarded as implicit behavioral indicators, as the individual performing the computer-based task is unaware of the intention to detect these specific indices (Giot et al., 2009). Conversely, during the execution of aIAT or

[6] The autobiographical Implicit Association Test (aIAT) is an implicit behavioral instrument that can detect autobiographical memories encoded in an individual's mind by measuring how quickly this person can categorize and associate sentences related to a specific event with the logical dimensions *true* and *false*. Faster categorization when an event (e.g., I went to Paris) is associated with the dimension *true* than *false* indicates that that specific event is encoded as true in the individual's mind. (source: Marini, M., Agosta, S., & Sartori, G. (2016). Electrophysiological correlates of the autobiographical implicit association test (aIAT): Response conflict and conflict resolution. *Frontiers in Human Neuroscience*, *10*, 391.)

[7] Reaction Times based Concealed Information Test (RT-CIT) is a memory detection technique based on the study of the response latencies to a stimulus of interest. It consists in presenting to the subject a critical information within a series of very similar, noncritical information. Innocents are expected to have similar reaction times (RTs) to all stimuli. By contrast, guilty subjects are expected to show longer response time for the critical item. (source: Verschuere, B., & Kleinberg, B. (2016). ID-Check: Online Concealed Information Test Reveals True Identity. *Journal of Forensic Sciences*, *61*, S237–S240. https://doi.org/10.1111/1556-4029.12960)

CIT-RT, the purpose of lie detection is explicitly communicated and known to the subject. Scientific literature has consistently demonstrated that the most reliable indicators of deception are the implicit behaviors that individuals involuntarily display (Sartori et al., 2018). Therefore, the optimal circumstances for uncovering deception occur when the examinee is unaware of both the lie detection objective and the parameters being recorded, known as *covert deception detection*.

Mouse dynamics can be defined as the description, in terms of spatial and temporal characteristic, of the user's behavior with a computer-based pointing device, such as a touchpad or a mouse (Jorgensen & Yu, 2011). In contrast to RT-CIT or aIAT, where respondents typically use keyboard buttons to provide answers, *mouse tracking* requires participants to select response labels displayed on the computer screen by clicking with the mouse. Utilizing the mouse input offers several advantages over keyboard-based responses. While pressing buttons only allows for the recording of response times (RTs), mouse usage enables the collection of additional indicators such as speed, acceleration, and trajectory (Monaro et al., 2017). *Mouse tracking* specifically allows for the plotting of mouse trajectory along two orthogonal axes, x and y, during the timeframe in which participants respond to stimuli presented on the computer monitor. Consequently, it can capture the cognitive load involved in stimuli processing during the response to multiple-choice questions. In summary, *mouse tracking* provides a valuable depiction of the cognitive processes underlying task performance, including those involved in generating deceptive responses (Freeman et al., 2011).

Duran and colleagues (2010) were the first to demonstrate that the kinematic mouse tracking index offers insights into detecting deception. The researchers conducted a study where they compared the mouse trajectories of participants who were instructed to either lie or tell the truth about their biographical information. Using a Nintendo-Wii controller, the authors measured various mouse trajectory parameters, including onset time, total response time, trajectory, speed, and acceleration of movement as participants responded to questions displayed on a screen. The findings revealed that during deceptive responses, mouse movements were slower and more erratic. Additionally, they exhibited a curvature towards a competing truthful response label, indicating the presence of conflicting response tendencies when lying.

Recently, Monaro et al. (2017; 2017) conducted a series of experiments utilizing the *unexpected question technique* in conjunction with *mouse tracking* to identify counterfeit identities. Participants were instructed to respond to both expected and unexpected yes-or-no questions regarding their biographical information. Using the mouse, they selected the correct alternative answer displayed on the computer screen. Half of the participants provided truthful responses, while the other half were instructed to respond according to a previously memorized false identity. The researchers examined spatial and temporal indices, such as the x and y coordinates of the mouse position during response time, the number of directional changes along the x-axis and y-axis, the initiation time (time taken to commence mouse movements after question appearance), the total response time (RT), the time to reach the maximum deviation point, the acceleration, and the speed over time. Additionally, the authors calculated the accuracy, which represents the number of errors made by participants while answering the questions. The findings of these studies demonstrated that individuals asserting a fabricated identity made a higher number of errors, took longer to complete the mouse responses, and exhibited broader trajectories. Notably, the mouse trajectories of liars and truth-tellers differed both visually and statistically, particularly for unexpected questions. Truth-tellers responding to unexpected questions displayed more direct trajectories, whereas liars initially moved more along the y-axis and experienced a delay in deviation towards the response button compared to truth-tellers. These patterns mirrored the cognitive load associated with lying and its impact on reaction times. By combining *mouse tracking* with the *unexpected question technique*, the accuracy in detecting false identities surpassed 95%. Furthermore, when focusing solely on responses to unexpected questions that required different category labels, the accuracy improved to 97.5-100%.

To overcome the yes-no structure imposed by *mouse tracking* and to tailor identity deception detection to the online context, specifically within the framework of online subscriptions or authentication, *keyboard dynamics* can be employed (Monaro et al., 2018; 2019).

Keyboard dynamics involve the analysis of precise temporal information pertaining to the rhythm of typing. It accurately captures the timing of key presses and releases as an individual types on a computer or mobile phone keyboard, providing detailed insights into the typing behavior (Moskovitch et al., 2009; Teh et al., 2013). As proven by Grimes et al. (2013) by performing an analysis of a person's typing pattern on a computer keyboard, typical cues to deceit can be detected. Specifically, liars display distinctive writing patterns that significantly differ from one another, in contrast to the relatively consistent patterns exhibited by truthful individuals, which do not deviate significantly from the average values.

Derrick et al. (2013) conducted an experiment involving computer-based interviews, where prompts provided by the system guided participants to respond deceptively or truthfully to each question. The authors identified four key indices for analysis: response time, number of changes (e.g., BACKSPACE and DELETE keystrokes), number of words, and lexical diversity. The findings showed a positive correlation between lying and both response time and number of edits, while revealing a negative correlation with word count.

In another study by Monaro et al. (2018), participants were tasked with answering control, expected, and unexpected questions related to their assigned true or false identities. Their responses were typed into an edit box using a computer keyboard, and the ENTER key was pressed to confirm each response. A comprehensive range of typing and non-typing features were collected, including: the total number of errors, the delay between the onset of the question and the first key press, the overall response time from stimulus onset to ENTER key press, the time interval between the first key press and the ENTER key press, the time span from the last key press to the ENTER key press, the number of characters pressed for each response, average writing speed, timestamps for each key press and release, time intervals between press and release of each key, time gaps between release of one key and press of the next, total press and release times for two and three consecutive keys, and the frequency of SHIFT, DEL, SPACE. The results indicated that liars made more errors, exhibited longer reaction times between question onset and response initiation in the edit box, as well as in the time required to type the complete response and confirm it after the final letter was pressed. Specifically, liars demonstrated significantly higher error rates compared to truth-tellers when responding to unexpected questions, while error rates were similar for both groups when answering control and expected questions. Notably, liars produced approximately 27 times more errors than truth-tellers when responding to unexpected questions.

Monaro et al. (2019) further extended the application of the *keyboard dynamics* and validated it in a real web subscription scenario. Participants were instructed to complete an online form to subscribe a university chat system, providing either genuine or fabricated identity information, including name, surname, email, phone number, date of birth, place of birth, and place of residence. Once the online form was filled out, participants were presented with four unexpected questions, and their typing patterns were recorded. This experimental format emulated the typical situation of online forms, where users are required to complete a set of mandatory fields before creating a web account. The study findings reaffirmed that liars made a significantly higher number of errors compared to truth-tellers when responding to unexpected questions. Furthermore, liars exhibited longer response initiation times, writing durations, and confirmation times. Among the variables analyzed, the interval between the onset of the question on the computer screen and the first key press, as well as the total time from stimulus onset to the end of the response, emerged as effective indicators in distinguishing between liars and truth-tellers. These findings strongly support the use of response times to unexpected questions as reliable cues for detecting deceit. Interestingly, the authors demonstrated that even when participants were aware that unexpected questions would be asked, the technique of presenting unexpected questions and recording the typing patterns remained effective in unveiling deceptive responses regarding personal identities.

Nonetheless, a constraint associated with the experimental design was the absence of randomization in the presentation of control, expected, and unexpected questions. It has been demonstrated that, even when the *unexpected questions technique* is not implemented in the experimental design, the mere random presentation of control and target-expected questions can selectively increase liars' cognitive load (Debey et al., 2015). This occurs because liars need to switch between two opposing strategies during alternate lie-truth trials, resulting in a higher cognitive load and enhanced cues to deception (Kiesel et al., 2010; Monsell, 2003; Vandierendonck, et al., 2010). In fact, lying and telling the truth can be considered as distinct cognitive tasks (Foerster et al., 2016), and the process of switching between them leads to slower response times and a higher number of errors. Consequently, the *switch cost* can serve as an indicator of deception (Foerster et al., 2016).

In a recent study Monaro et al. (2021) found that the most accurate feature for discriminating between identity liars and truth-tellers is the *Inverse Efficiency Score* (IES) [8]. The IES is an index that considers both the speed and accuracy of the interviewees' responses. It considers the fact that participants can increase their response speed during the task, but this may result in a higher proportion of errors (PE). Liars' IES scores for unexpected questions were significantly higher compared to truth-tellers. These findings demonstrate that the *unexpected question technique*, when combined with response time measurement, can effectively expose deception with an accuracy rate of 98%, surpassing the accuracy achieved by techniques such as *mouse tracking* and *keyboard dynamics*. Unfortunately, all the study questions were in the form of affirmative sentences that required a yes-or-no response and, as the authors point out the main limitation

[8] The Inverse Efficiency Score (IES) considers the number of errors and increases proportionally the average RT of the subject according to the following formula: IES= RT / (1−PE) (source: Bruyer, R., & Brysbaert, M. (2011). Combining speed and accuracy in cognitive psychology: Is the inverse efficiency score (IES) a better dependent variable than the mean reaction time (RT) and the percentage of errors (PE)?. *Psychologica Belgica*, *51*(1), 5-13. https://doi.org/10.5334/pb-51-1-5)

of this technique is represented by the difficulty to apply it in ecological contexts (e.g., an investigative interview).

In sum, all the studies described in this last paragraph share the characteristic that participants were required to respond to closed-ended questions by clicking on the correct response label on the computer monitor, or they had to respond to open-ended questions by typing their answers using the computer keyboard. Participants never provided verbal responses to open-ended questions. Furthermore, the various question categories (control, expected, and unexpected) were frequently administered without randomization, thereby impeding the ability to further amplify the cognitive load on deceivers through the elicitation of *switch costs* resulting from *task switching*. All these features restrict the applicability of these procedures in ecological contexts, such as face-to-face investigative interviews.

To the best of our knowledge, there have been no published studies assessing the efficiency of employing the *unexpected question technique* in conjunction with the measurement of response times and errors to identify *identity deception* during face-to-face investigative interviews, where control, expected, and unexpected questions are randomly interspersed.

CHAPTER 3: THE RESEARCH

3.1 Research description and aims

The primary aim of the research is to evaluate if a *lie detection* technique that employs a reaction times paradigm mixed with the *unexpected questions technique* could correctly identify identity liars. In line with previous scientific research findings, we expect that response times and errors in response to unexpected questions will serve as the most reliable indicators to accurately differentiate between individuals who provide deceptive information about their identity and honest participants (Parkhouse & Ormerod, 2018; Monaro et al., 2017; Monaro et al., 2018; Monaro et al., 2019; Monaro et al., 2021). Liars, in fact, are unable to anticipate unexpected questions and, as a result, cannot rely on the *lie script* they typically prepare before an interview to verify the genuineness of their statements (Clemens et al., 2011). Clearly, refusing to answer would raise suspicion from the interviewer (Vrij et al., 2011), and for this reason, liars must quickly (1) inhibit the truthful response, (2) fabricate a deceptive answer, (3) substitute the deceptive response for the truthful one, and (4) ensure that the lie is credible and consistent with what they have already stated during the interview and with the information the interviewer already possesses. This process of information reconstruction elicited by unexpected questions increases cognitive load and leads to inaccurate and slow responses from deceivers (Parkhouse & Ormerod, 2018). In contrast, truth-tellers, relying on a trace of memory in response to unexpected questions, will produce more similar responses to those given to expected questions.

To further increase the cognitive load on deceivers, questions can be presented in a randomized manner during the interview, making use of a concept recognized in academic literature as the *switch cos*t (Kiesel et al., 2010; Monsell, 2003; Vandierendonck, et al., 2010). In the interview administered in our study, questions were not presented in distinct categories (control questions followed by expected questions and then unexpected questions); instead, the order was randomized, following a typical task switching design. This forced identity deceivers, in contrast to truth-tellers, to continuously switch between opposing cognitive strategies in response to the various question categories. In fact, lying and truth telling can be considered as discrete cognitive undertakings (Foerster et al., 2016). The approach adopted in responding to both expected and unexpected questions involved suppressing truthful responses and substituting them with deceptive responses. Conversely, when dealing with control questions, the strategy was to provide honest answers. In contrast, for truth-tellers, the sole approach throughout the interview was to respond honestly. This is precisely why deceivers, compared to truth-tellers, perform an additional cognitive task known as *task switching*, resulting in an enhanced cognitive load known as the *switch cost*, which is reflected in liars' task performance, characterized by higher response latencies and error rates (Foerster et al., 2016).

The distinct contribution of this study, compared to previous research in the field of *identity lie detection*, lies in evaluating of the effectiveness of *unexpected questions technique* combined with response times and errors analysis in unmasking identity liars within face-to-face investigative interviews.

3.2 Materials and Methods

This section will describe the participant sample, the experimental procedure, and the materials utilised for conducting the research.

3.2.1 Participants

The study sample comprised 60 participants who were native Italian speakers primarily residing in the regions of Veneto, Lombardy, Lazio, and Emilia Romagna. All participants were university students aged between 21 and 29 years, averaging 23.68 (SD=1.32). Specifically, the study involved the participation of 34 females (57 %) and 26 males (43 %), with an equal distribution of males and females across the two experimental conditions, with a range of educational backgrounds between the ages of 16 and 19 years (M=17.82; SD=0.59).

3.2.2 Experimental procedure

The current study was conducted within the Department of General Psychology (D.P.G.) at the University of Padua. The Ethics Committee for Psychological Research at the University of Padua approved the experimental procedure.

The participants were recruited through the experimenter's personal network and word-of-mouth. No extrinsic incentives (such as monetary rewards or university credits) were provided to the participants. The participants were randomly assigned to one of two experimental conditions: 30 participants belonged to the honest experimental condition and were instructed to respond to the interview questions consistently with their true personal information, while the other 30 participants belonged to the faking experimental condition and were instructed to respond to the interview questions by providing false information according to the fictitious identity assigned to them. Prior to commencing the experiment, participants received assurances regarding the anonymity of their data, which were solely utilised for the research purposes of the current study. The participants were informed of their option to withdraw from the research at any time, without providing explanations or facing any form of penalty, ensuring the non-utilization of their data. Each participant reviewed the informed consent form and, by signing it, made a voluntary decision to participate in the research.

The experiment consisted of five phases, described as follows.

Phase 1: Participants in the honest condition were instructed to fill out a PDF file on their personal computer containing their actual personal information, including their name, surname, date of birth, first six letters of the tax code, place of birth, place of residence, address, telephone number, email, completed three-year degree course, and the year in which the three-year degree title was obtained. In contrast, participants in the faking condition were given five minutes to memorise personal identification data related to a fictitious identity assigned to them by the experimenter. The false data to be memorized were the same as those requested from participants in the honest experimental condition.

Phase 2: All participants, regardless of whether they were in the honest condition or the faking condition, were required to perform five arithmetic operations. This mental distracting task was employed to ensure that false personal information were not only retained in short-term memory but also encoded into long-term memory.

Phase 3: All participants, both in the honest group and the faking group, were required to recall either their true or fictitious personal information orally. Participants in the faking group could proceed to the next phase of the interview only if they did not make any errors during the recall of the false personal information. In cases where participants made errors in repeating the false personal information, they were given an additional five minutes to learn the information, perform five more arithmetic operations, and then recall the information a second time. If no errors were made during this second recall, they would proceed to the interview phase. However, if errors were made, the procedure would be repeated. The implementation of the procedure described in phases 2 and 3, as previously employed by Monaro and colleagues (2021) in their research, was intended to ensure that false personal information in the faking group were not only retained in short-term memory but also encoded into long-term memory so that subjects could recall their fake identity for the whole duration of the experiment.

Phase 4: All participants were administered an interview consisting of 36 open-ended questions, as listed in the Appendix. The interview was conducted in person and lasted approximately five minutes per participant. The interview procedure was standardised for all participants. Before commencing the interview, each participant was provided with the following instruction: "*I will now ask you questions regarding the personal information you provided earlier in the experiment*." The interview consisted of 12 control questions, 12 expected questions, and 12 unexpected questions. The control, expected, and unexpected questions were presented in a randomized manner. The interview was audio-recorded from the beginning, which allowed for the extraction and analysis of reaction times, specifically the time elapsed between the end of the interviewer's question and the start of the participant's response.

Phase 5: After completing the interview, all participants were required to fill out two questionnaires using *Google Forms* [9]. The questionnaires aimed to investigate the perceived difficulty level of responding to each interview question on a *Likert scale* ranging from 1 to 5, and the degree of anticipation for each interview question on a *Likert scale* ranging from 1 to 3.

The overall duration of the five phases was approximately 40 minutes.

3.2.3 Stimuli

Expected questions pertained to personal information (whether accurate or fabricated) that were explicitly and directly stated in the PDF file, such as name, address, and date of birth. The correct answer to this specific set of questions was automatically retrievable, for both honest and faking individuals, since it could be directly derived from true or false personal information provided.

Unexpected questions concerned information that, although not explicitly reported in the PDF file nor retrieved in phase 3, could be extracted from the basic personal information provided within the PDF. These questions elicit an automatic response in the case of truth-tellers and a non-automatic response for liars. For example, if someone's date of birth is September 20th, they would likely know their zodiac sign is Virgin; similarly, if they resided in Padua, they should know the region’s capital. Conversely, liars, being unfamiliar with the false personal information assigned to them, were forced to quickly reconstruct the correct response based on that false information.

[9] *Google Forms* is a survey administration software included as part of the free, web-based Google Docs Editors suite offered by Google. The app allows users to create and edit surveys online while collaborating with other users in real-time. The collected information can be automatically entered into a spreadsheet (source: https://en.wikipedia.org/wiki/Google_Forms).

Finally, control questions pertained to the circumstances of the experiment or to directly verifiable physical characteristics. These are questions to which even liars cannot lie, since the interviewer directly verifies the truthfulness of the answer. Analyzing the response latency to these questions allows for the calculation of the average time it takes for an individual subject to respond sincerely to a question. Utilizing control questions, researchers can compare the known and certain truthful responses of each experimental subject with the answers whose truthfulness needs to be assessed.

All the interview questions are listed in the Appendix, first categorized into control, expected, and unexpected questions, and then randomized in the same manner they were presented to the participants.

3.2.4 Materials

The interviews were recorded using the *Voice Memos* [10] application downloaded on an *Apple* mobile phone.

Subsequently, the extraction of response times for each interview was performed using the *Audacity Software* [11], which allows for precise calculation of response latencies down to the millisecond.

Finally, the two post-interview questionnaires were administered using the *Google Forms* [12] application, a Google tool that enables the collection of information through customized questionnaires and automatic linking of participant responses to a spreadsheet.

[10] *Voice Memos* is a voice recording app introduced on iPhones with the release of iPhone OS 3, on Macs introduced on macOS Mojave, and on iPads introduced with iOS 12 (before, it could only be installed unofficially on iPads) designed for saving short snippets of audio for later playback. Saved voice memos can be shared as a .m4a file or can be edited, which allows parts of a recording to be replaced, background noise to be removed, or the length of a recording to be trimmed. Other playback options include the ability to change playback speed, skip silent parts of a memo, or enhance a recording. Audio files can also be organised into different folders. (source: https://en.wikipedia.org/wiki/Pre-installed_iOS_apps)
[11] *Ivi, p.36.*
[12] *Ivi, p. 59.*

3.2.5 Research hypothesis

Drawing upon a comprehensive literature review in the field of deception, we expect the following: (H1) Due to the information reconstruction process elicited among identity deceivers by unexpected questions, response times and error rates in the two groups will primarily vary for the unexpected questions; (H2) Relative to truth-tellers, identity liars, who are required to continuously switch between two opposing cognitive tasks (telling the truth and lying) in response to various question categories, are expected to demonstrate greater response times and errors, irrespective of the question category, as an expression of *switch costs*; (H3) Since lying involves the engagement of executive functions, including the inhibition of a truthful prepotent response, identity liars will exhibit longer response times and more errors for expected questions compared to control questions; however, these differences will be smaller than those shown in the comparison with unexpected questions; (H4) Identity liars will experience greater cognitive challenges when responding to unexpected questions compared to honest participants.

As liars have not prepared answers to unanticipated questions, they cannot rely on the *lie script* (Clemens et al., 2011) that they typically develop prior to the interview. When confronted with unexpected questions, liars lack sufficient time to plan a deception and must spontaneously invent an answer. They must then inhibit the true response and replace it with the lie, while also mentally verifying that the interviewer cannot easily detect the lie. These complex cognitive operations, required by the liar in response to unexpected questions, are a result of the information reconstruction process. This process imposes a higher cognitive load, leading to longer response times and reduced accuracy in the liar's responses. Consequently, slowness and inaccuracy in answering unexpected questions serve as diagnostic indicators of deception (Parkhouse et al., 2018). In contrast, truth-tellers experience more comparable levels of cognitive load when responding to both expected and unexpected questions, as they can draw upon genuine memories of events. As a result, truth-tellers produce more comparable answers to these questions (Vrij, 2014).

Furthermore, lying and truth-telling can be regarded as distinct cognitive processes (Foerster et al., 2016). Thus, given the randomized order of presentation of the three question categories in the administered interview, identity liars, as opposed to truth-tellers, were compelled to continuously switch between opposing cognitive strategies in response to the various question categories. As a result, apart from the cognitive load imposed by unexpected questions on deceivers, an additional cognitive load termed *switch cost* becomes evident in the task performance of individuals engaging in deception, characterized by higher response latencies and error rates (Kiesel et al., 2010; Monsell, 2003; Vandierendonck, et al., 2010). Switch costs reflect a residual effect, also referred to as proactive interference (PI), resulting from the execution of a prior, competing task (Wylie & Allport, 2000). This residual effect from the previous task set facilitates performance when the same task is repeated over time. However, when the task alternates with another task (as is the case when questions requiring different response strategies are randomly presented), the previously performed task introduces interference and must be inhibited (Allport et al., 1994; Koch et al., 2010).

CHAPTER 4: DATA ANALYSIS AND RESULTS

4.1 Introduction to the statistical analysis conducted

As described in paragraph 3.2.1, the 60 participants were randomized into the two conditions of honesty and faking to have 30 participants for each of experimental conditions. Once the response times were encoded and errors were counted, it was possible to proceed with the data analysis. Response time refers to the duration between the completion of the interviewer's question and the initiation of the interviewee's response. The initiation of the response was defined as the first semantically meaningful word uttered by the interviewee, excluding any filler words such as "*umm*" or "*well*". Errors were identified as responses that did not align with the participant's personal information (whether true or false) and responses in which the participant claimed to not know the correct answer. The statistical analyses were conducted using the *JASP software* [13].

4.2 Latency based measures analyses and results

First, we conducted *a Shapiro-Wilk test* [14] to assess the assumption of normality of our dataset, which is often required for many statistical analyses, such as parametric tests like t-tests. If the *p-value* associated with the test is greater than the chosen significance level ($p > 0.05$), then the data can be considered approximately normally distributed, allowing for the application of parametric tests. Conversely, if *the p-value* is below the significance level ($p < 0.05$), it suggests that the data significantly deviate from a normal distribution, indicating the need for alternative non-parametric tests. The results of *the Shapiro-Wilk test* indicate that most of the variables included in our dataset deviate from a normal distribution. Based on the results of the *Shapiro-Wilk test*, we employed a *Mann-Whitney non-parametric test*

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[13] *Jeffreys's Amazing Statistics Program* (JASP) is a free and open-source program for statistical analysis supported by the University of Amsterdam. It offers standard analysis procedures in both their classical and Bayesian form (source: https://en.wikipedia.org/wiki/JASP)

[14] *The Shapiro–Wilk test* is a test of normality. It was published in 1965 by Samuel Sanford Shapiro and Martin Wilk. The *Shapiro–Wilk test* tests the null hypothesis that a sample $x_1, ..., x_n$ came from a normally distributed population. (source: https://en.wikipedia.org/wiki/Shapiro–Wilk_test)

[15] to investigate whether there were statistically significant differences ($p < 0.05$) in the collected data between liars and truth-tellers.

Table 1

Descriptive and Statistical Analysis of the honest and faking conditions.

Variables	Descriptives			
	Mean	SD	W	Rank-Biserial Correlation
Reaction times c_H	0.82	0.48	666.5**	0.48
Reaction times c_F	1.21	0.39		
Reaction times e_H	0.77	0.61	717.5***	0.59
Reaction times e_F	1.36	0.44		
Reaction times u_H	1.72	2.26	890***	0.98
Reaction times u_F	5.90	0.76		
Errors c_H	2.78×10^{-3}	0.02	450	0.00
Errors c_F	2.78×10^{-3}	0.02		
Errors e_H	5.56×10^{-3}	0.06	634***	0.41
Errors e_F	0.05	0.02		
Errors u_H	0.07	0.18	890***	0.98
Errors u_F	0.39	0.05		

Note. Mean, Standard Deviation (SD), value of the W-statistic (W), p-value, and Effect size in each honest (H), faking group (F). Each variable is represented in two rows. For example, the first two rows of the table should be read as follows: Reaction times c_H defines the variable reaction times for control questions in honest (H) condition, while F in faking condition. Effect size is given by the matched Rank Biserial Correlation.
* $p < 0.05$ **$p \leq .01$***$p<.001$

As observed in *Table 1*, deceivers exhibit longer average reaction times across all three question types (control, expected, and unexpected), although the greatest difference in average response times between faking and honest groups is observed within the category of unexpected questions. Moreover, deceivers demonstrate a higher average error rate compared to honest individuals, both in response to

[15] In statistics, the *Mann–Whitney U test* (also called *Wilcoxon rank-sum test*, or *Wilcoxon–Mann–Whitney test*) is a nonparametric test of the null hypothesis that, for randomly selected values X and Y from two populations, the probability of X being greater than Y is equal to the probability of Y being greater than X. (source: https://en.wikipedia.org/wiki/Mann–Whitney_U_test).

expected and unexpected questions. Notably, both groups make an equal number of errors when responding to control questions, and honest participants exhibit an inverse pattern in response times compared to deceivers, as they show, on average, shorter response times to expected questions compared to those obtained for control questions. By observing the *p-values* reported in *Table 1*, it can be noted that a statistically significant difference was found between the two groups, honest and faking, for the following variables: reaction times to control questions; reaction times to expected questions; reaction times to unexpected questions; errors in expected questions; and errors in unexpected questions. Therefore, it can be concluded that there is a statistically significant difference between the two groups for all investigated variables, except for errors in response to control questions, where no difference was found across the two groups.

For the *Mann-Whitney test*, the *effect size* is given by the *Rank-Biserial correlation coefficient* [16]. Analyzing the *effect size* of each investigated variable, it can be observed that only for reaction times and errors in response to unexpected questions, the *effect size* is notably large (0.98). Thus, the greatest difference between the two groups is observed in reaction times and errors in response to unexpected questions as identity liars exhibit significantly longer response times and more errors compared to honest participants for unexpected questions. The two experimental groups also significantly differ in reaction times for control questions and expected questions, while the *effect size* obtained for these variables is medium (the *effect sizes* range from 0.48 to 0.59). Identity liars, compared to truth-tellers exhibit longer response times for both expected and control questions and make more errors in response to expected questions. Finally, no difference (*p-value* > 0.05) was found between the two groups regarding errors in response to control questions.

[16] A method of reporting the *effect size* for the *Mann–Whitney U test* is with a measure of rank correlation known as the *Rank-Biserial correlation coefficient*. Edward Cureton introduced and named the measure. *Rank-Biserial correlation coefficient* can be interpreted similarly to the *Pearson correlation coefficient* as it can assume values between -1 and 1. Therefore, a *Rank-Biserial correlation coefficient* close to -1 or 1 suggests that the ranks of observations are largely consistent with group membership, conversely, a value close to zero suggests that there is no systematic difference in the ranking order between the two groups. (source: doi:10.1007/BF02289138. S2CID 122500836.)

Next, we conducted a *Wilcoxon signed-rank test* [17] to assess if there were statistically significant differences between the variables within the faking group. More specifically, we compared the following pairs of variables: (1) reaction times for unexpected and control questions; reaction times for unexpected and expected questions; (3) reaction times for expected and control questions; (4) errors for unexpected and control questions; (5) errors for unexpected and expected questions; (6) errors for expected and control questions. The results of the *Wilcoxon signed-rank test* are reported in *Table 2*.

Table 2

Descriptive and Statistical Analysis of the faking condition.

Variables	Descriptives			
	Mean	SD	W	Rank-Biserial Correlation
Reaction times_u	5.90	2.26		
Reaction times_c	1.21	0.48	465***	1.00
Reaction times_u	5.90	2.26		
Reaction times_e	1.36	0.61	465***	1.00
Reaction times_e	1.36	0.61		
Reaction times_c	1.21	0.48	337*	0.45
Errors_u	0.39	0.18		
Errors_c	2.78×10^{-3}	0.02	465***	1.00
Errors_u	0.39	0.18		
Errors_e	0.05	0.06	465***	1.00
Errors_e	0.05	0.06		
Errors_c	2.78×10^{-3}	0.02	114**	0.90

Note. Mean, Standard Deviation (SD), value of the W-statistic (W), p-value, and Effect size in each couple of variables. Each couple of variables is represented in two consecutive rows. Effect size is given by the matched Rank Biserial Correlation.
$* p < 0.05$ $**p \leq .01$ $***p < .001$

[17] The *Wilcoxon Signed-Rank Test* is a non-parametric alternative to the *paired t-test* applied in the case of a single sample with two paired measurements. It hypothesizes that the dependent variable is derived from a continuous random variable measurable on at least interval scales. (source: https://it.wikipedia.org/wiki/Test_dei_ranghi_con_segno_di_Wilcoxon)

For all the considered pairs of variables, as indicated by the *p-value* being lower than the significance level of 0.05, a statistically significant difference is observed. Furthermore, the *effect size* is large for all pairs of variables (the *effect sizes* range from 0.90 to 1.00), except for the comparison between reaction times for expected and control questions, where the *effect size* is moderate (0.45). Therefore, it is possible to conclude that the deceivers have longer response times for unexpected questions compared to control and expected questions, and they also have longer response times for expected questions compared to control questions, although the difference is smaller compared to that observed in the comparison with unexpected questions. Additionally, they make more errors in response to unexpected questions compared to control and expected questions, and they make more errors in response to expected questions compared to control questions.

Subsequently, we conducted an additional *Wilcoxon signed-rank test* to examine whether the same pattern of differences between variables existed within the honest group. Analyzing the results of the *Wilcoxon signed-rank test* reported in *Table 3*, it can be observed that there is a statistically significant difference (*p-value* $<.001$) for the following pairs of variables: (1) response times to unexpected and control questions; (2) response times to unexpected and expected questions; (3) errors on unexpected and control questions; (4) errors on unexpected and expected questions. The *effect size* observed in the comparison between the aforementioned pairs of variables is strong, with *a Rank-Biserial Correlation coefficient* ranging from 0.98 to 1.00. Therefore, honest participants, like the identity liars, also exhibit longer response times and more errors for unexpected questions compared to control and expected questions. Unlike liars, the honest group do not exhibit statistically significant differences (*p-value* > 0.05) in the comparison between response times to expected and control questions and errors in response to expected and control questions. It is interesting to note that honest participants exhibit an inverse pattern in response times compared to deceivers when comparing expected and control questions.

Table 3

Descriptive and Statistical Analysis of the honest condition.

Variables	Descriptives			
	Mean	SD	W	Rank-Biserial Correlation
Reaction times_u	1.72	0.76		
Reaction times_c	0.82	0.39	464***	1.00
Reaction times_u	1.72	0.76		
Reaction times_e	0.77	0.44	461***	0.98
Reaction times_e	0.77	0.44		
Reaction times_c	0.82	0.39	165	- 0.24
Errors_u	0.07	0.05		
Errors_c	2.78×10^{-3}	0.02	253***	1.00
Errors_u	0.07	0.05		
Errors_e	5.56×10^{-3}	0.02	231***	1.00
Errors_e	5.56×10^{-3}	0.02		
Errors_c	2.78×10^{-3}	0.02	4	0.33

Note. Mean, Standard Deviation (SD), value of the W-statistic (W), p-value, and Effect size in each couple of variables. Each couple of variables is represented in two consecutive rows. Effect size is given by the matched Rank Biserial Correlation.
* $p < 0.05$ **$p \leq .01$***$p < .001$

In *Table 3*, it can be observed that, although the difference in response times between these two question types is not statistically significant (*p-value* > 0.05), the *Rank-Biserial Correlation coefficient* assumes a negative value (- 0.24). This indicates that truth-tellers exhibit longer response latency to expected questions compared to control questions, a pattern that is not observed in the faking group. Indeed, identity liars show significantly longer response times to expected questions compared to control questions, with a moderate *effect size* of 0.45.

4.3 Manipulation Check

As mentioned in paragraph 3.2.2, after the experimental interview was concluded, the participants completed two questionnaires on *Google Forms*. The first questionnaire assessed the level of anticipation for each expected and unexpected question of the interview on a *Likert scale* ranging from 1 to 3 (where 1 corresponded to "*slightly anticipated*" and 3 to "*highly anticipated*"). The instructions were as follows: "*Below are some of the questions you had to answer during the just-concluded interview. Please indicate, on a scale from 1 to 3, how much you expected these questions to be asked, where 1 corresponds to slightly and 3 corresponds to highly*". This questionnaire allowed us to verify whether participants indeed perceived unexpected questions as unforeseen compared to expected questions.

We performed a *Wilcoxon signed-rank test* to examine whether a statistically significant difference ($p < 0.05$) existed between the variables anticipation for expected questions and anticipation for unexpected questions. The results of the *Wilcoxon signed-rank test* are reported in *Table 4*.

Table 4

Descriptive and Statistical Analysis of the honest and faking conditions.

Variables	Descriptives			
	Mean	SD	W	Rank-Biserial Correlation
Anticipation_e	2.75	0.31	1813.5***	0.98
Anticipation _u	1.49	0.23		

Note. Mean, Standard Deviation (SD), value of the W-statistic (W), p-value, and Effect size in the considered pair of variables. Effect size is given by the matched Rank Biserial Correlation.
* p < 0.05 **p ≤.01***p<.001

On average, both honest and faking participants perceived expected questions as more anticipated compared to unexpected questions. A statistical significant difference between the two variables (*p value* <.001) with a strong *effect size* was found, as indicated by the *Rank-Biserial correlation coefficient* (0.98). Therefore, we can conclude that the participants perceived the interview questions categorized as unexpected as significantly more unpredictable than the questions categorized as expected.

The second questionnaire assessed the level of perceived difficulty by participants in responding to control, expected, and unexpected questions of the interview on a *Likert scale* ranging from 1 to 5. The instructions were as follows: "*Below are the questions you had to answer during the just-concluded interview. Please indicate, on a scale from 1 to 5, the level of difficulty you perceived in answering these questions" (1 = "very easy"; 2 = "quite easy"; 3 = "normal"; 4 = "quite difficult"; 5 = "very difficult").* This questionnaire allowed us to investigate whether participants in the faking group indeed perceived the unexpected questions as more difficult compared to participants in the honest group (H4).

We conducted two *Wilcoxon signed-rank tests* to investigate if there were statistically significant differences within the two groups in the perceived difficulty in responding to the three different categories of questions ($p < 0.05$). The results are reported in *Table 5*. On average, deceivers perceived responding to expected questions as more cognitively demanding compared to control questions and answering to unexpected questions as more cognitively demanding than expected questions. Conversely, for the honest participants, there was no difference in the perceived level of difficulty between responding to control and expected questions. However, also for honest participants the perceived level of difficulty for unexpected questions was higher on average compared to the other two categories of questions. As evident, in both groups, statistically significant differences (*p-value* <.001) with an extremely strong *effect size* (1.00) were found in the perceived difficulty when comparing responses to unexpected-control and unexpected-expected questions. However, the two groups differ in the comparison of perceived difficulty in responding to expected-control questions. While the faking group showed a statistically significant difference (*p-value* <.001) with a strong *effect size* (0.76), no statistically significant difference was found for the honest participants in the comparison of perceived difficulty between responding to expected and control questions (*p-value* > 0.05).

Table 5

Descriptive and Statistical Analysis of the honest and faking conditions.

Variables	Descriptives [a]			
	Mean	SD	W	Rank-Biserial Correlation
Difficulty u_H	1.99	0.37	465***	1.00
Difficulty c_H	1.26	0.25		
Difficulty u_F	2.87	0.65	465***	1.00
Difficulty c_F	1.21	0.25		
Difficulty u_H	1.99	0.37	465***	1.00
Difficulty e_H	1.26	0.18		
Difficulty u_F	2.87	0.65	465***	1.00
Difficulty e_F	1.61	0.49		
Difficulty e_H	1.26	0.18	182.5	0.04
Difficulty c_H	1.26	0.25		
Difficulty e_F	1.61	0.49	358***	0.76
Difficulty c_F	1.21	0.25		

Note. Mean, Standard Deviation (SD), value of the W-statistic (W), p-value, and Effect size in each couple of variables. Each couple of variables is represented in two consecutive rows, The same couple of variables is reported first for the honest condition (H) and then for the faking condition (F). Effect size is given by the matched Rank Biserial Correlation.
* $p < 0.05$ **$p \leq .01$***$p<.001$

Therefore, both honest participants and deceivers rated responding to unexpected questions as more cognitively challenging compared to control and expected questions. However, only identity liars perceived responding to expected questions as more cognitively difficult than responding to control questions.

Then we performed a *Mann-Whitney test* to explore whether there were statistically significant differences in the perceived difficulty in responding to control, expected and unexpected questions between identity liars and truth-tellers. The results of the *Mann-Whitney* test are presented in *Table 6*.

Table 6

Descriptive and Statistical Analysis of the honest and faking conditions.

Variables	Descriptives			
	Mean	SD	W	Rank-Biserial Correlation
Difficulty c_H	1.26	0.37	384	- 0,15
Difficulty c_F	1.21	0.25		
Difficulty e_H	1.26	0.65	649**	0.44
Difficulty e_F	1.61	0.25		
Difficulty u_H	1.99	0.37	795.5***	0.77
Difficulty u_F	2.87	0.18		

Note. Mean, Standard Deviation (SD), *p-value*, and *effect size* in each honest (H), faking group (F). Each variable is represented in two rows. For example, the first two rows of the table should be read as follows: Difficulty c_H defines the variable perceived difficulty for control questions in honest (H) condition, while F in faking condition. Effect size is given by the matched Rank Biserial Correlation.
* $p < 0.05$ **$p \leq .01$***$p<.001$

The *p-value* below 0.05 obtained for the variables difficulty for expected questions and difficulty for unexpected questions indicate the presence of a statistically significant difference between the two groups in the perceived difficulty in responding to expected and unexpected questions. However, no statistically significant difference is found between the two groups in the level of perceived difficulty in responding to control questions (*p-value* > 0.05). The *Rank-Biserial Correlation coefficient* of 0.77 indicates a strong *effect size* for the perceived difficulty in responding to unexpected questions, while a medium *effect size* (0.44) was found for the perceived difficulty in responding to expected questions. Therefore, the identity liars rated responding to both unexpected and expected questions as more cognitively challenging compared to the sincere participants, although the difference between the two groups is more pronounced for the category of unexpected questions. Additionally, the two groups did not differ in their assessment of the difficulty for control questions.

4.4 Machine Learning

As a final analysis, the accuracy of correctly classifying identity liars and truth-tellers was evaluated through the application of *Machine Learning* (ML) models. By utilizing machine learning, we can indeed shift our focus towards predicting the individual human behavior rather than explaining the behavior of a group of subjects (Zago, Piacquadio, & Monaro, 2019).

To perform this analysis, the following features were taken into account:

- Response times to control questions;
- Response times to expected questions;
- Response times to unexpected questions;
- Errors on control questions;
- Errors on expected questions;
- Errors on unexpected questions.

The implemented *Machine Learning* procedure is the *K-fold cross validation* [18] (K=10), a model where the data sample is divided into 10 distinct groups (Kohavi, 1995). The algorithm is trained on the first 9 blocks, referred to as training groups, to learn from the data and classify between honest and faking individuals. Subsequently, the algorithm is tested on the tenth block to evaluate its learning capability. This process is repeated 10 times, where the algorithm is trained and tested on different blocks. Each fold comprised 54 subjects in the training set (90%) and 6 subjects in the test set (10%). The subjects in the training and test sets were distinct for each fold. Therefore, the algorithm was tested on all 60 participants. At the end of the procedure, several performance values are calculated for each algorithm, including accuracy, Area Under the Curve (AUC), recall, precision and F1-score. These values indicate the goodness percentage of the model's performance.

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[18] *K-fold cross-validation*, also known as cross-validation, involves dividing the entire dataset into k equally sized parts. At each step, one of these k parts becomes the validation set, while the remaining parts constitute the training set. In other words, the sample is divided into groups of equal size, and one group is iteratively excluded while attempting to predict it using the non-excluded groups. This process allows for assessing the quality of the prediction model utilized (source: https://en.wikipedia.org/wiki/Cross-validation).

Table 7 presents the performance values resulting from the implementation of the top-performing five algorithms. As evident from *Table 7*, the algorithm that exhibited the best performance indices is *Extreme Gradient Boosting* algorithm.

Table 7

Values of the investigated performance indices for the top five algorithms are presented.

Model	Performance indices				
	Accuracy	AUC	Recall	Precision	F1
Extreme Gradient Boosting	0.96	0.97	1.00	0.95	0.97
Random Forest Classifier	0.96	1.00	1.00	0.93	0.96
Decision Tree Classifier	0.94	0.94	0.95	0.95	0.93
Adaboost Classifier	0.94	0.97	0.95	0.95	0.93
Gradient Boosting Classifier	0.94	0.97	0.95	0.95	0.93

*Note.*The table presents the performance index values for the top six implemented algorithms. The indices are listed in the columns, while the algorithms on which they were applied are listed in the rows.

An additional analysis was conducted to evaluate the occurrence of false positives and false negatives across ten distinct folds. A false positive occurs when an honest subject is mistakenly classified by the algorithm as a liar, whereas a false negative occurs when a liar is erroneously classified as honest. Below, for each of the ten folds, the number of false positives and false negatives is reported:

- Fold 1 - False Positives: 0, False Negatives: 0
- Fold 2 - False Positives: 0, False Negatives: 1
- Fold 3 - False Positives: 0, False Negatives: 0
- Fold 4 - False Positives: 0, False Negatives: 0
- Fold 5 - False Positives: 1, False Negatives: 0

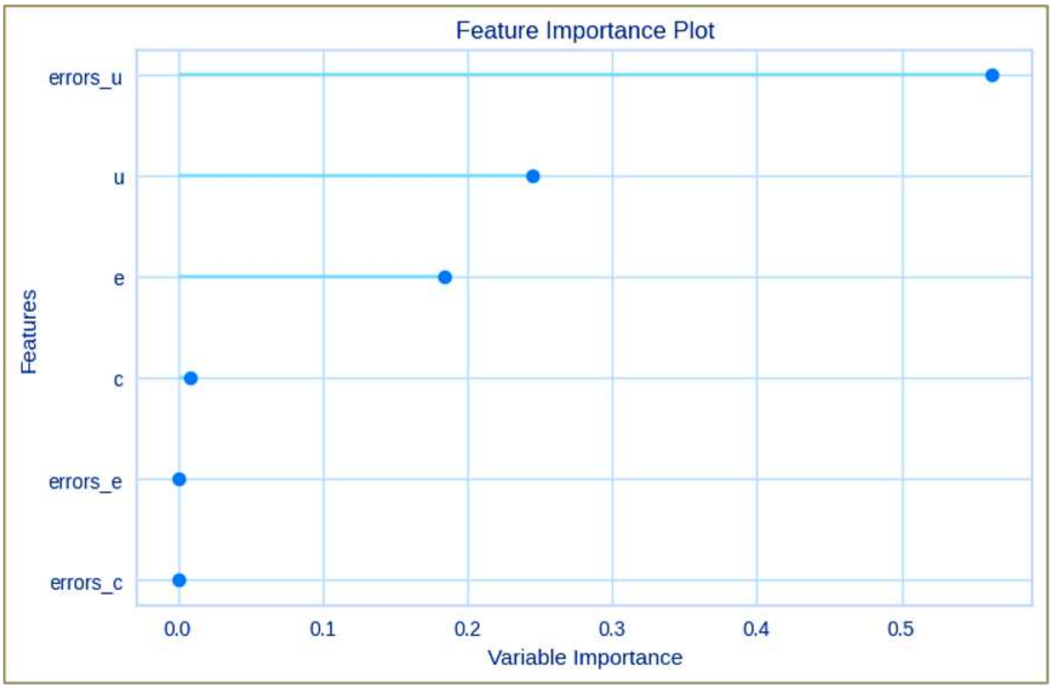
- Fold 6 - False Positives: 0, False Negatives: 0
- Fold 7 - False Positives: 0, False Negatives: 0
- Fold 8 - False Positives: 0, False Negatives: 0
- Fold 9 - False Positives: 0, False Negatives: 0
- Fold 10 - False Positives: 0, False Negatives: 0

Across the ten folds, there were only one false positive (in fold 5) and one false negative (in fold 2), resulting in an average of 0.1 false positives and an average of 0.1 false negatives. Thus, *Extreme Gradient Boosting* algorithm has demonstrated a high level of effectiveness, exhibiting a minimal occurrence of classification errors.

The Feature Importance Plot, reported in *Figure 1*, represents the influence of each input variable on the model, providing a better understanding of which factors affect the predictions and offering insights into the relationships between variables.

Figure 1

Feature importance plot



Note. The plot illustrates, along the x-axis, variable importance, representing the degree of influence, on a scale from 0.0 to 0.5, of each variable on the model. Along the y-axis, the six input variables are listed, ordered from the one with the greatest influence on the model to the one with the least influence.

In this case, the errors on unexpected questions variable (errors_u) is the one that best helps discriminate between honest and dishonest individuals, closely followed by u variable, which represents the average response times to unexpected questions.

CHAPTER 5: RESULTS DISCUSSION AND CONCLUSIONS

In this section, the aims of the experimental study, the research hypotheses, and the methodologies employed will be summarized concisely. Additionally, results will be discussed in light of the existing literature, along with the emerged limitations, and potential future directions to be pursued.

5.1 Structure, objectives, and research hypotheses

The principal objective of this study was to assess the efficacy of a *lie detection* approach that combines a reaction time paradigm with the *unexpected questions technique* for accurately identifying individuals providing deceptive information about their identities.

Both deceivers and honest participants, alike, cannot anticipate unexpected questions posed by the interviewer. The disadvantage for those engaging in deception is that, as they cannot pre-plan a *lie script* and thereby reduce the cognitive load (Clemens et al., 2011), they are compelled to swiftly undertake a multifaceted process involving (1) inhibiting their truthful response, (2) constructing a deceptive answer, (3) substituting the deceptive response for the truthful one, and (4) ensuring that the fabricated lie is both credible and consistent with their prior interview statements and the information already possessed by the interviewer. This process of information reconstruction, triggered by unexpected questions, imposes a heightened cognitive load, resulting in inaccurate and delayed responses from those engaging in deception (Parkhouse & Ormerod, 2018). In contrast, truth-tellers, who rely on a memory trace when responding to unexpected questions, are expected to provide responses more comparable to those given for anticipated questions.

Given these premises, the experimental paradigm entailed randomly allocating the 60 participants into two distinct groups: the honest and the faking group. Honest participants were asked to fill out a PDF file with their personal information. At the same time, the liars were instructed to memorize fictitious personal data assigned to them by the experimenter. Subsequently, all participants underwent an interview consisting of 36 open-ended questions. All participants were informed that the interview contained questions about the personal information (either true or false) provided earlier in the experiment.

Honest participants were required to respond with their genuine personal information. In contrast, participants in the faking condition were instructed to answer consistently with the fictitious identity assigned to them by the experimenter in the earlier phase.

The interview questions consisted of 12 control questions, 12 expected questions, and 12 unexpected questions, which were presented in a randomized order (in the Appendix, the *Table 9* containing the randomized list of questions). This was done to add to the cognitive load induced on deceivers by unexpected questions, an additional cognitive load known in the literature as *switch cost*, which manifests in the task performance of individuals engaging in deception, characterized by higher response latencies and error rates (Kiesel et al., 2010; Monsell, 2003; Vandierendonck et al., 2010). The switch cost arises from the fact that lying and truth-telling can be considered distinct cognitive tasks (Foerster et al., 2016). Consequently, deceivers, in contrast to truth-tellers, must employ different strategies to respond correctly to the various question categories in the interview. To answer both expected and unexpected questions, they must suppress truthful responses and replace them with deceptive responses. Conversely, when dealing with control questions, the strategy is to provide honest answers. In contrast, for truth-tellers, the consistent approach throughout the interview is to respond truthfully.

The interviews were audio-recorded to enable subsequent encoding of response times and errors.

Immediately after the interview, participants were asked to complete two questionnaires that assessed, using a Likert scale, the degree of anticipation and the perceived difficulty level in responding to each interview question.

The distinctive aspect of this research, differentiating it from prior studies in the field of identity deception detection, lies in its examination of the efficacy of combining the *unexpected questions technique* with response time analysis in unmasking identity deceivers in face-to-face investigative interviews.

Drawing upon a comprehensive literature review in the field of deception, we expected the following: (H1) Due to the information reconstruction process elicited among liars by unexpected questions, response times and error rates in the two groups will primarily vary for the unexpected questions; (H2) Relative to truth-tellers, liars, who are required to continuously switch between two opposing cognitive tasks (telling the truth and lying) in response to various question categories, are expected to demonstrate greater response times and errors, irrespective of the question category, as an expression of *switch costs*; (H3) Since lying involves the engagement of executive functions, including the inhibition of a truthful prepotent response, identity liars will exhibit longer response times and more errors for expected questions compared to control questions; however, these differences will be smaller than those shown in the comparison with unexpected questions; (H4) Identity liars will experience greater cognitive challenges when responding to unexpected questions compared to honest participants.

5.2 Discussion

In the following subsections, the results obtained from both the statistical analyses conducted on response times and errors in response to interview questions, and the Manipulation check questions administered at the end of the interview to investigate perceived difficulty and question anticipation levels will be discussed. Additionally, results from applying Machine Learning models will be addressed.

5.2.1 Discussion of the results derived from the statistical analysis

The analysis of the results showed that liars exhibit significantly longer response times for unexpected questions than honest participants. Additionally, liars make significantly more errors for the same category of questions than truth-tellers. The greatest difference between the two groups is observed in reaction times and errors in response to unexpected questions. Therefore, we can confirm hypotheses 1 of our study.

Those results, align with existing literature, showing that deceivers exhibit longer response times and make significantly more errors than honest individuals for unexpected questions (Derrick et al., 2013; Monaro et al., 2017; 2018; 2019; 2021). Given that unexpected questions are in no way predictable, they can be considered as a rehearsal- averting strategy. Consequently, while the information needed to answer an unexpected question is readily accessible and automatic for an honest subject, a liar must engage in mental calculations to retrieve the necessary information and construct a response (Vrij et al., 2009). Since liars haven't prepared answers for unforeseen questions, they cannot rely on the *lie script* they typically prepare before the interview (Clemens et al., 2011). As a result, when confronted with unexpected questions, liars must fabricate an answer, inhibit the actual response and substitute it with the lie, and finally, mentally verify that the lie is not easily detectable by the interlocutor. These intricate mental processes required of liars, stemming from the information reconstruction process prompted by unexpected questions, result in an increased cognitive load. This heightened cognitive load leads to longer response times and reduced response accuracy making slowness and inaccuracy in answering unexpected questions one of the most effective diagnostic indicators of deception (Parkhouse et al., 2018; Monaro et al., 2021).

Although the greatest difference between the two groups is observed in reaction times and errors in response to unexpected questions, identity liars, compared to honest participants, show significantly longer response times for the expected and control questions and significantly greater errors for expected questions but not for control questions. However, the *effect size* observed for these two question categories is moderate and not as strong as that found for response times and errors in response to unexpected questions. Therefore, we can partially confirm hypotheses 2 of our study.

In our study, in contrast to the usual presentation format of the three question categories within the interview, the questions were presented randomly. For this reason, it is possible to attribute the observed increase in response times (RTs) among identity liars compared to truth-tellers, even when considering control and expected question categories, and the concurrent rise in errors specifically for expected questions to the *switch cost* resulting from *task switching* (Kiesel et al., 2010; Monsell, 2003; Vandierendonck, et al., 2010). This refers to the cognitive burden experienced by liars when adopting opposing response strategies for control and expected questions. In our study, identity liars, instead of truth-tellers, had to continuously switch between opposite strategies to respond to the three types of questions. For control questions, they were compelled to answer truthfully, as the veracity of their response could be directly and easily evaluated by the interviewer. However, they had to respond by lying to unexpected and expected questions, adopting an opposite strategy to that used in response to control questions. In fact, for a liar, responding to either a target-expected or unexpected question necessitates a prior knowledge of the truth, followed by a strategic switch (Sheridan & Flowers, 2010). This, in turn, introduces an additional cognitive element into the response process. The continuous cognitive and strategic switching forced upon identity liars influences their task performance, leading to increased response times (RTs) and higher error rates (Foerster et al., 2016). This rationale underpins the potential use of *switch cost* as an indicator of deception.

Furthermore, honest and dishonest participants showed no differences in errors for control questions, committing an equal number of errors on average. This result aligns with the analyses on the perceived difficulty in responding to interview questions. No differences were found in the perception of difficulty responding to control questions. However, compared to honest participants, identity liars perceived it as more difficult to respond to expected and unexpected questions. This latter finding aligns with the poorer performance of liars, compared to truth-tellers, regarding both response times and errors, specifically in response to expected and unexpected questions.

Identity liars committed more errors for unexpected questions compared to control and expected questions, and for expected questions compared to control questions. The observed *effect sizes* were extremely strong, although the smallest *effect size*, albeit still very strong, was found in the comparison of errors on control and expected questions. Similarly, identity liars showed higher response times for unexpected questions compared to control and expected questions, and for expected question compared to control questions. Although the *effect size* observed in the comparison of response times to unexpected and expected questions, as well as unexpected and control questions, is extremely strong, a moderate *effect size* was found in the comparison of response times to control and expected questions.

In sum, identity liars exhibited less pronounced differences between response times and errors to control questions and expected questions, while displaying more pronounced differences between response times and errors to control questions and unexpected questions, and between response times and errors to expected and unexpected questions. Therefore, we can confirm hypotheses 3 of our study as well.

This result is intuitive, given that the framework from which the unexpected questions technique originates, known as the *Cognitive Load Approach* (CLA) , is fundamentally based on selectively increasing cognitive load on deceivers to further impair their performance, which is already compromised by the act of deception, which is inherently cognitive demanding compared to truth-telling (Vrij et al., 2006; Vrij et al., 2012; Walczyk et al., 2013; Blandón-Gitlin et al., 2014; Masip & Herrero, 2015).

In the conducted study, the observation that participants displayed noticeably extended reaction times and increased error rates when responding to anticipated questions (i.e., questions in which deceivers were instructed to provide false information) in comparison to control questions (i.e., questions requiring truthful responses) can be understood by considering the imperative involvement of executive functions when individuals engage in deception. These executive functions encompass higher-order cognitive processes, such as the inhibition of a truthful prepotent response (referred to as *inhibitory control*, which serves as an essential mechanism for withholding truthful information), and the retention of factual verity within cognitive awareness while concurrently devising a novel and appropriate deceptive response (relying on the capacity of *working memory*) (Gombos, 2006; Spence et al., 2001; 2004). To date, substantial evidence supports the notion that, when lying, an initial activation of truthful information occurs and subsequently necessitates inhibition (Debey et al., 2014; Vartanian et al., 2013). This two-step process has been demonstrated to lead to an increase in response times for individuals engaging in deception (Walczyk et al., 2003; 2009; 2014), aligning with our findings. Furthermore, scientific research on the development of lying ability in children has demonstrated that it develops alongside the ongoing development of executive functioning, especially inhibition (Carlson et al., 1998). Also the *kinematic analysis of mouse movements* allows for the discrimination between deceptive and truthful responses, as exemplified by Duran et al. (2010). work. During deceptive responses, mouse movements manifest as slower and more erratic compared to those during truthful responses. Additionally, they exhibit a curvature towards a competing truthful response label, indicating the presence of conflicting response tendencies when lying. Similarly, Hadar et al. (2012) demonstrated that prior to a deceptive response, motor-evoked potentials (MEPs) in the primary motor cortex associated with the fingers corresponding to the truthful response (the one that needs to be inhibited) are greater than those associated with the fingers corresponding to the deceptive response (the one that needs to be provided). It is important to emphasize, in conclusion, that several neuroscientific studies have corroborated the activation of neural regions associated with executive functioning within the nervous system when individuals engage in deception. For instance, Johnson and colleagues (2002), as well as Langleben et al. (2002) and Christ et al. (2009), have illustrated that individuals engaged in deception display activation of the anterior cingulate cortex (ACC), a cerebral region involved in inhibiting prepotent responses and monitoring conflicting response tendencies.

At the same time, the smaller difference in response times and errors when comparing control and expected questions is consistent with findings reported in the existing literature. Control questions are ones that even liars cannot deceive since the interviewer can directly verify the truthfulness of the answer. On the other hand, expected questions are predictable since they concern the main topic on which the interview is about and whose truthfulness has to be ascertained. As extensively demonstrated in the literature, liars often prepare a *lie script* (Granhag et al., 2003; Granhag & Strömwall 2007; Clemens et al., 2011) to respond to anticipated questions, thereby reducing their cognitive load during the interview. They can rely on their memory instead of spontaneously fabricating a convincing narrative if these questions are asked. In line with this, a substantial body of literature has indeed demonstrated that the more premeditated a lie is, the more response times decrease, rendering it a less reliable indicator of deception (Littlepage & Pineault, 1985; DePaulo et al., 2003; Zuckerman et al., 2003; Walczyk et al., 2009; Walczyk et al., 2012).

Within the honest group, a similar pattern was observed: unexpected questions, compared to expected and control questions, required longer response times and more errors. This outcome is consistent with Parkhouse & Ormerod's study (2018), which demonstrated that responding to unexpected questions is cognitively more challenging even for truth-tellers. This outcome is consistent with the findings of Parkhouse & Ormerod's study (2018), which demonstrated that responding to unexpected questions is cognitively more challenging even for truth-tellers.

However, two discrepancies were observed in this group compared to the faking group: no differences were found in errors on expected and control questions, nor in reaction times for expected and control questions.

This result can be attributed to the absence, among the truth-tellers, of an increased cognitive load due to *task switching*. It can be asserted that, unlike identity liars, honest individuals do not need to employ different cognitive strategies to respond to control and expected questions, nor do they have to constantly switch between these strategies during the interview to answer correctly and avoid errors.

Conversely, honest individuals consistently employ the same strategy to respond to all the interview questions: telling the truth (Sheridan & Flowers, 2010). In the pertinent academic literature, it is firmly established that the phenomenon known as the *switch cost* is characterized by participants exhibiting diminished performance in terms of increased response times and higher error rates when transitioning between alternate tasks, as opposed to when they engage in repetitive execution of the same task, such as telling the truth (Kiesel et al., 2010; Monsell, 2003; Vandierendonck, et al., 2010). Furthermore, for honest individuals, the cognitive strategy to be employed in responding to expected questions is easier because it does not necessitate, as is the case of identity liars, prior awareness of the truth followed by a strategic switch from truth to deceit. This, in turn, does not introduce an additional cognitive element into the response process (Sheridan & Flowers, 2010). Likely, the task performance of truth-tellers (i.e., their response times and error rates) on expected questions does not differ from that displayed for control questions.

Additionally, within the honest group, a reverse pattern was observed in comparing response times to expected and control questions as opposed to the faking group. Although the detected difference was not statistically significant, honest participants, on average, exhibited longer response latencies to expected questions compared to control questions.

5.2.2 Discussion of the results derived from the Manipulation Check questions

From the statistical analysis conducted on the *Manipulation Check* questions asked after the interview, it emerged that participants perceived the unexpected questions as significantly more unpredictable than expected ones. Therefore, it can be concluded that the questions in the interview have been appropriately designed and categorized into three types (i.e., control, expected, and unexpected). More specifically, the unexpected questions posed pertained to spatial and temporal details and shifts, such as "*How old will you be in 2025?*", "*Name two regions that border the region where you reside,*" "*What is the capital city of your region of* *residence?", "Is your birthdate closer in time to Christmas or Easter?"*, and personal information that can be derived from participants' identity cards, such as "*What is your zodiac sign?*" or "*How old are you?*". These types of questions have been employed in previous studies and have been demonstrated to be effective in eliciting cues to deceit in liars (Monaro et al., 2021; Lancaster et al., 2013; Vrij et al., 2009; Leins et al., 2011).

For deceivers, responding to both expected and unexpected questions was cognitively more challenging than honest individuals, although a greater difference between the two groups was observed for unexpected questions. Thus, hypothesis 5 was confirmed. This result is consistent with the findings of Parkhouse & Ormerod (2018), in which liars found the interview questions more challenging than truth-tellers, regardless of the question type (expected or unexpected).

However, it is important to specify that both honest individuals and deceivers reported a significantly higher level of difficulty in responding to unexpected questions compared to expected questions and greater difficulty with unexpected questions than control questions. Once again, this result aligns with the finding obtained in Parkhouse & Ormerod's study (2018), where all interviewees found the unanticipated questions more cognitively demanding than the anticipated questions, regardless of the veracity condition. This suggests that, while lying is inherently more challenging than telling the truth, the use of unanticipated questions increases the cognitive load for both liars and truth-tellers.

One difference observed between the two experimental groups was that, for deceivers, responding to expected questions was more cognitively challenging than responding to control questions. This effect was not found in the group of honest individuals, where no differences in perceived difficulty in responding to these two types of questions emerged. This result aligns with the absence of differences in errors and response times to expected and control questions within the group of honest participants. A potential explanation for why identity liars experience a higher cognitive load in response to expected questions compared to control questions lies in the fact that answering falsely to an expected question, as compared to truthfully responding to a control question, necessitates prior knowledge of the truth followed by a strategic switch (Sheridan & Flowers, 2010), thereby introducing an additional element into the response process.

5.2.3 Discussion of the results derived from the Machine Learning analysis

In conclusion, the performance evaluation in classifying identity liars and truth-tellers was conducted by applying *Machine Learning* (ML) models. ML specifically focuses on the predictive power of models in discriminating between liars and truth-tellers, aligning with our research goals.

As shown in *Table 7*, the achieved level of accuracy was 96%, with an average of 0.1 false positives and an average of 0.1 false negatives. The two features showing the highest discriminatory power between the two categories (honest vs. faking) were errors in response to unexpected questions and response times to unexpected questions. The achieved accuracy level of 96% in discriminating between identity liars and honest individuals is similar to that reported by previous authors (Monaro et al., 2017; 2018; 2019; 2021). Furthermore, the predictors demonstrating the highest discriminatory power, namely (1) the errors in response to unexpected questions and (2) the response times to unexpected questions, align with findings from prior studies (Monaro et al., 2017; 2018; 2019; 2021) demonstrating the essential contribution of unexpected questions in accurately discriminating between liars and truth-tellers.

5.3 Emerging limitations and future directions

Despite the successful execution of the experiment, it is certainly not immune to limitations that are crucial to acknowledge and address. First and foremost, the experiment was conducted on a sample of university students aged 21 to 29 years. This aspect does not allow for generalization to older or younger age groups, which should be explored separately.

The artificiality of the laboratory replication naturally reflects in the participants' motivation to lie. Unlike investigative interviews in real-world settings, where individuals are highly motivated to ensure that their lies are not exposed, the laboratory setting can be considered a low-stakes situation where participants' motivation for successfully concealing their lies is not particularly high. Even if exposed, deceivers did not face any punishment or consequences, contrasting with real investigative contexts. Therefore, it would be advisable in a future study to provide compensation to dishonest participants, allowing them to experience a genuine motivational incentive to engage in as credible deception as possible.

Additionally, according to Vrij et al. (2010) findings, there is a positive correlation between the perceived gravity of a lie and the cognitive load it imposed. Thus, it is possible that in a real-world high-stakes setting, such as an investigative interview, liars may exhibit more noticeable cues to deception.

The most significant limitation of the conducted study was the inability to have the audio recordings of the interviews coded by a different experimenter than the one who conducted the interviews. Clearly, coding by another researcher would have been preferable to enable a double-blind assessment in the study.

However, starting with these limitations is essential to improve the experimental design and plan future studies. Undoubtedly, it would be necessary to test the experimental paradigm on a more representative population sample, encompassing various age groups and including individuals from different social statuses.

Finally, as previously explained in section 2.1, most identity deceivers only partially modify their real biographical information (Wang et al., 2004), aiming to reduce cognitive effort in the act of deception. Given this, it would be intriguing to investigate whether the technique of unexpected questions remains effective even in cases of minimal identity alteration.

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APPENDIX

Table 8

List of questions categorized by type

Control questions	Expected questions	Unexpected questions
1. In which month are we currently?	1. What is your last name?	1. How old are you?
2. What year is it?	2. What is your first name?	2. In which region were you born?
3. Which season are we in?	3. What undergraduate degree did you complete?	3. How old will you be in 2025?
4. In which city are you located at this moment?	4. In which city were you born?	4. List the first three digits of your phone number in reverse order.
5. In which region of Italy are you currently situated?	5. In which city do you reside?	5. Name two regions that border the region where you reside.
6. What color are your eyes?	6. What year were you born?	6. What is the capital city of your region of residence?
7. How tall are you?	7. What are the last three digits of your phone number?	7. What are your initials?
8. What shoe size do you wear?	8. What is your email address?	8. How many odd numbers are in your date of birth?
9. What color are your shoes?	9. In which month were you born?	9. What is your zodiac sign?
10. What is the color of your hair?	10. In which year did you earn your bachelor's degree?	10. How old were you in 2011 when you earned your bachelor's degree?
11. What color is the shirt you are wearing?	11. What are the first six letters of your tax identification code?	11. Is your birthdate closer in time to Christmas or Easter?
12. What is your gender?	12. What is your residential address?	12. What is the capital city of your region of birth?

Table 9

Standardized list of questions

Standardized list of questions
1. What is the capital city of your region of birth?
2. Where were you born?
3. What is the color of the shirt you are wearing?
4. What is the capital city of your region of residence?
5. What is your residential address?
6. In which city do you reside?
7. What is your zodiac sign?
8. How many odd numbers are in your date of birth?
9. In which region of Italy are you currently located?
10. What are the last three digits of your phone number?
11. What year is it?
12. What color are your eyes?
13. What is your first name?
14. In which month were you born?
15. How old are you?
16. What are your initials?
17. What undergraduate degree did you complete?
18. What are the first three digits of your phone number in reverse order?
19. In which season are we currently?
20. In which year were you born?
21. What is your gender?
22. What color are your shoes?
23. What is your email address?
24. In which year did you earn your bachelor's degree?
25. How tall are you?
26. What shoe size do you wear?
27. What shoe size do you wear?
28. How old were you in year X when you earned your bachelor's degree?
29. In which month are we currently?
30. Name two regions that border the region where you reside.
31. What is your last name?
32. What color is your hair?
33. Is your birthdate closer in time to Christmas or Easter?
34. How old will you be in 2025?
35. In which city are you located at this moment?
36. What are the first six letters of your tax identification code?