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Decrypting lying: What happens when we tell lies?

A pilot study

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Abstract

The present study is the first that attempts to describe the production of deceptive messages on the level of speech production. When lying, two kinds of information are processed at once: the truth and the lie. Despite general agreement on the activation of the truth during lying, little is known about the extent to which the truth is co-activated during lie production. Based on previous evidence, we hypothesize that the truth causes interference at the phonological level during lying. To investigate this matter, we introduce a new experimental design, in which we presented participants with truth-related and lie-related distracter words, similar as in a picture-word interference task, to investigate their effects on truth telling and lying. Our results reveal no significant effect of truth-related distracters on lying. However, we can show that lies are co-activated during phonological encoding when participants tell the truth. We explain this finding by the fact that participants prepared to lie in advance of each trial, as the environment we created was lie-encouraging. Thus, we conclude that a lie can be co-active during truth telling under certain circumstances. Based on our results, we can show that the introduced design is apt for the investigation of speech production and suggest further research relying on this design.

Keywords: Deception, Speech production, Picture-word interference, Mediated semantic interference

Decrypting lying: What happens when we tell lies? – A pilot study

Lies and deceptive communication are not only very frequent phenomena in everyday life (DePaulo, Kashy, Kirkendol, Wyer, & Epstein, 1996), but they also seem to function effortlessly, which is why it is so hard for other humans to detect lies and other forms of deception (e.g. Porter & ten Brinke, 2008; Hadjistavropoulos, Craig, Hadjistavropoulos & Poole, 1996 ; Enos et al., 2006; Vrij , 2004; see Burgoon, 2015 for review). Yet, this appearance is deceptive itself: telling a lie takes longer than telling the truth (Suchotzki, Verschuere, Van Bockstaele, Ben-Shakhar, & Crombez, 2017) and in fact, lying requires more mental effort then truth telling (e.g. Pennebaker & Chew, 1985; Vrij & Granhag, 2012). The idea that lying is cognitively more challenging compared to truth telling is widely accepted, however the reasons of the increase of cognitive effort when lying have still not yet been fully understood and remain a popular research topic.

Many researchers explain the cognitive effort that is associated with lying by the fact that two types of information are being processed at once: the truth and the lie (Spence et al., 2001; Walczyk, Harris, Duck & Mulay, 2014; Buller & Burgoon, 1996; Vendemia, Schillaci, Buzan, Green & Meek, 2009; see Gombos, 2006 for a review). The idea that the truth is involved in lying is self-explanatory: only if the deceiver is aware of what is true a realistic lie can be produced. Hence, it is not surprising that a popular view is that the increase of cognitive control and the prolonged reaction times (hereafter RT) can be attributed to the fact that the truth is the more dominant response than the lie, meaning the truth is automatically activated during speech production and from that moment on conflicts with lie production (Walczyk et al., 2014). In order to prevent lie detection, the truth needs to be suppressed from the moment of its activation (e.g. Suchotzki, Crombez, Debey, Van Oorsouw & Verschuere, 2015; Verschuere, Spruyt, Meijer

& Otgaar, 2011; Williams, 2012). As a matter of fact, several studies could show that brain areas associated with response monitoring, cognitive control, or response inhibition, such as the dorsolateral prefrontal cortex (DLPFC) and the inferior frontal gyrus (IFG), are more activated during lying than during truth telling (e.g. Nuñez et al., 2005; Ito et al., 2012; Abe et al., 2007; Priori et al, 2007; Ganis, Kosslyn, Stose, Thompson, Yurgelun-Todd, 2003; Walczyk, Igou, Dixon & Tcholakian, 2013; Yin, Reuter & Weber, 2016; see Gamer & Ambach, 2014 and Hughes et al., 2005 for review). The role of the IFG in response inhibition (hereafter RI) has been demonstrated in several studies using response inhibition tasks, during which participants showed strong activation of the IFG (Swick, Ashley & Turken, 2008; Verbruggen & Logan, 2008). Furthermore, patients with IFG lesions perform much worse in stop-signal tasks than healthy participants (Aron, Fletcher, Bullmore, Sahakian, & Robbins, 2003). A theoretical framework which views the truth as embedded in the process of lie production is the Activation-Decision-Construction-Action Theory (ADCAT; Walczyk et al., 2014). According to the ADCAT the production process can be split into four components, which are executed parallel-to-serial: (1) the automatic activation of the truth and the encoding of the social context (Activation component), (2) the decision whether to lie or tell the truth (Decision component), (3) the construction of a plausible alternative to the truth (Construction component), and (4) the inhibition of the truth as well as the incorporation of the desired response in the speech production system or its non-verbal communication (Action component).

Despite most of the research highlighting the conflicting role of the truth during lying, counterproposals about the role of the truth in the act of deception have been made. Debey, De Houwer, and Verschuere (2014) for example, were able to show that facilitating the conceptual encoding of the truth by increasing its relative activation actually reduced deception RTs (cf.

Seymour, 1977). To explain these seemingly counterintuitive findings the authors proposed a new theory of lying: the two step-hypothesis (TST). According to the TST, in a first step the truth is retrieved from memory, based upon which the lie can be generated in the second step. Therefore, the facilitation of the first step of truth activation is speeding up the production process of lying. In contrast to the ADCAT, the TST claims that the initial activation of the truth is not necessarily and in interference with the lie, but rather constitutes a cue required for a successful lie. It follows, that truth and lie may not be competitors but the truth might play a functional role during deception.

Hence, whilst many researchers agree that the activation of the truth is the first step in the process of lying (Walczyk et al., 2014; Debey et al., 2014), there is dissent about the role of the co-processed truth and evidence is sparse. An idea which incorporates evidence for the functional as well as the interfering role of the truth states that the truth might either be functional or interfering depending on the processing stage of lie production (Debey et al., 2014). Thus, it can be hypothesized that during decision making for or against lying, the facilitated retrieval of the truth should speed up the process of lying, since knowing the truth is an essential information necessary to decide for or against lying (Williams, Bott, Patrick, & Lewis, 2013). Likewise, the truth can facilitate the construction of a plausible lie by serving as a cue to construct a lie (Walczyk, Roper, Seemann, & Humphrey, 2003). In fact, lies that are close to the truth are much harder to detect (Vrij, Granhag, & Mann, 2010). During speech production on the other hand, evidence is scant. Yet, some studies' results suggest that the co-activation of truth and lie causes interference. For instance, lying leads to more speech errors compared to truthful naming (Sporer & Schwandt, 2006), which is typically evidence for hindered speech production (e.g. Hartsuiker & Kolk, 2001). Interestingly, the increased error frequency observed during lying, as well as slower naming times, can be supressed if the speech production is facilitated, e.g. by rehearsing verbal responses beforehand (Hu, Chen, & Fu, 2012). Further, measures of verbal efficiency, such as noun-verb association task performance, semantic access times and word naming latencies, correlate with and predict lie RTs but not truth telling RTs (Walczyk et al., 2003). From these findings Walczyk et al. derived the idea that lying is a constructive process involving the access and manipulation of linguistic codes, insofar as the retrieved information is deliberately falsified to generate a convincing lie. In contrast, truth telling does not involve manipulation during the retrieval of the truth. The increased RTs compared to truth telling that lying is linked to might therefore be explained by the additional information processed during speech production, which explains the response conflict of lie and truth responses and the inhibition of the latter (Farrow, Hopwood, Randolph, Michael, & Spence, 2010). On the grounds of this evidence, we therefore hypothesize that the truth and the lie are co-activated during speech production when lying. Whilst some studies explicitly addressed deception construction and decision making (e.g. Foerster, Wirth, Kunde, & Pfister, 2017), to our knowledge no study has provided an adequate explanation of the processes during speech production. Therefore the purpose of this study is to understand the effects of a possible co-activation of the truth during lying.

Language production and the co-activation of truth and lie

Models of speech production and key assumptions

To understand how the truth might be activated during speech production when lying, a review of the models of speech production is helpful. Most models distinguish three core processing stages with different time courses (e.g. Dell, 1986; Roelofs, 1992; Levelt, Roelofs, & Meyer, 1999). These three stages usually are (a) the retrieval of a conceptual representation, (b) the retrieval of an abstract lexical representation and (c) access to the phonological information: First, the representation of the target's concept is selected (conceptual level), which then activates the appropriate lexical candidate (also lemma; lexical level). In the third step, the phonological code of the selected lemma is retrieved, which forms the basis of the articulatory motor program (word form level; Levelt, 1999). To describe the flow of information within the speech production system, most of the models of speech production have adopted the spreading activation principle: During speech production, not only the conceptual representations of the target utterance, but also competing lexical concepts are activated. For example, when naming a picture (e.g. "table"), multiple related concepts such as "wood", "chair", "leg" are activated as well. It is assumed as well that the activated conceptual nodes pass activation onto the level of lexical selection and their corresponding lemmas are activated as well (e.g. Dell, 1986; Dell & O'Seaghdha, 1991). Thus, at the lexical level, the appropriate candidate is selected from several co-activated entries. Furthermore, evidence suggests that co-activated lemmas forward some of the activation to their word forms (e.g. Peterson & Savoy, 1998; Abdel Rahman & Melinger, 2008). Yet, there is disagreement to whether phonologically co-activated word forms reflect exceptions to a general rule or if concurrently activated word forms are simply difficult to detect (e.g. Jescheniak & Schriefers, 1998).

Parallel to word encoding, the outcomes are self-monitored to prevent speech errors (Levelt, 1983), but also socially inappropriate utterances (Dhooge & Hartsuiker, 2011). To this date, it is still being debated which stages of speech production are involved in monitoring. Earlier theories, such as the perceptual loop theory, suggest that internal and external speech are monitored by the language comprehension system (Levelt et al., 1999). On the other hand, recent evidence suggests that monitoring involves domain general processes which detects conflict between response options as well as errors (Gauvin, De Baene, Brass, & Hartsuiker, 2016). Self-monitoring is especially important during speech production of affective content, as well as to prevent potentially inappropriate or unpleasant utterances in social communicative situations (Dhooge & Hartsuiker, 2011). As lying usually serves the purpose to cover up socially unpleasant messages, self-monitoring might play an important role when lying.

A potent tool to investigate co-activation patterns during speech production is the classic picture-word interference (PWI) paradigm. During this task, participants are instructed to name pictures whilst ignoring presented distracter words. A prominent finding that was made in PWI experiments is that naming pictures in the presence of distracters belonging to the same semantic category (e.g. SHIRT, *trousers*) is slowed down, and more erroneous than naming with unrelated distracters presented (*semantic interference effect*, e.g. Glaser & Düngelhoff, 1984; Aristei & Abdel Rahman, 2013). The presence of semantic interference has usually been interpreted as evidence of delayed lemma selection due to the enhanced concurrent activation of several related lemmas via shared semantical features (lexical competition). The reduction of naming times when distracter words phonologically similar to the target word (e.g. SHIRT, *ship*) are presented, is usually interpreted as evidence for increased activation of the target phonological nodes, which leads to facilitated phonological encoding (*phonological facilitation effect,* e.g. Lupker, 1982; Meyer & Schriefers, 1991). When distracter words phonologically related to a semantic competitor are presented, the naming times increase. This phenomenon is called *mediated semantic interference effect* (e.g. Abdel Rahman & Melinger, 2008; Levelt et al., 1991). For example, when naming a picture of a PYRAMID, the distracter word *camera* is slowing the naming, as it is phonologically related to a competitor of pyramid, namely CAMEL. The *mediated semantic interference effect* has been used as evidence for the co-activation of categorical as well as non-categorical associates that spread activation to their phonological nodes via feedback mechanisms (Melinger & Abdel Rahman, 2012). Lastly, phonological distracters related to non-targets have been shown to prolong naming times under special circumstances, which has been interpreted as a sign of phonological co-activation of several word forms (Jescheniak, 1997).

Key assumptions about the co-activation of truth and lie for our study

In the light of evidence suggesting that the truth and lie are co-activated during the language production of lying, as well as evidence demonstrating that such a co-activation can occur at several levels during speech production, the main interest of the current study is to localize the stage of processing at which the truth interference effect occurs. As a successful lie has to be realistic (Millar & Tesser, 1988), it should be somewhat related to the truth concept. Therefore, it seems self-evident that truth and lie are related conceptually. For example, when a husband asks his wife where she had been during the day, the range of realistic answers is limited by the knowledge that the partners share about each other (DePaulo & Kashy, 1998). In line with this idea, Debey and colleagues (2014) showed that an increase of the conceptual activation of the truth relative to the lie facilitates deception (cf. Seymour, 1977). Thus, we can assume that truth and lie are co-active during conceptual encoding.

In terms of the co-activation of truth and lie at the lexical level, we know that RT's of word naming, semantic access and noun-verb association tasks predict lie production times, whilst they do not predict the latency of truth retrieval (Walczyk et al., 2003). Despite their correlative nature, the results of prolonged naming times when lying might reflect enhanced semantic interference, which can be compensated by a high score of verbal efficiency. Since only the truth is active during truth retrieval, its production times are not predicted by the same measures as deception production (Walczyk et al., 2003). Thus, we hypothesize that truth and lie are concurrently co-activated during lying, which should reflect in delayed lemma selection.

Whether truth and lie are co-activated during phonological encoding is less clear due to lack of studies on the matter. Yet, evidence for a co-activation of truth and lie can be found in research on monitoring. Studies investigating emotional speech production and appropriateness monitoring suggest that the monitoring processes are located after word form encoding (Severens, Kühn, Hartsuiker & Brass, 2011; Motley, Camden & Baars, 1981; Motley, Camden & Baars, 1982). In line with this, recorded event-related potentials (ERP) show that error detection and correction does not occur until 600 ms after a stimulus to name had been displayed (Severens, Janssens, Kühn, Brass, & Hartsuiker, 2011) As lying is associated with the intent to conceal socially inappropriate messages (DePaulo et al., 1996), late monitoring for appropriateness, which secures accurate and taboo-free speech, might also play a major role in lying. Possibly, the co-processed truth plays a role similar to a co-activated taboo word, and is therefore not inhibited until after word form encoding. Hence we hypothesize that truth and lie are co-active at the word form level during the speech production of lying.

Our study is an attempt to improve the understanding of the act of deception. So far, no study has provided an adequate investigation of the co-activation of truth and lying during deceptive speech production. This study is therefore the first to explore the speech production of lying. Consistent with previous findings, we hypothesize a concurrent co-activation of truth and lie during speech production as people lie. More precisely, we predict that the truth is co-active semantically and phonologically during speech production when lying. Such a finding could help explaining interfering effects the truth has on lying, e.g. prolonged naming and semantical access when lying.

The present study

The main aim of the present study was to investigate the role of the truth during lying and the locus of the response inhibition mechanism in the time course of speech production. For this purpose, we used a new experimental design, which allowed us investigating deceptive speech production with the PWI task. Since deception is defined as “a (. . .) deliberate attempt, without forewarning, to create in another a belief which the communicator considers to be untrue” (Vrij, 2008), we tried to avoid instructed deception, as suggested by (Sip, Roepstorff, McGregor, & Frith, 2008). Additionally, it is important to consider the social components of lying: detectability, as well as the risk of social confrontation, modulate deceptive behaviour (Sip et al., 2013). A well-planned deception study should thus avoid instructed lies and let participants face an instance, which controls and confronts them. A challenge that arises when following these suggestions is obtaining comparable trial numbers for honest and deceptive behaviour without explicitly instructing it. To bypass this problem, Kireev, Korotkov, Medvedeva, and Medvedev (2013) instructed their participants to make a claim about the identity of a playing card they were presented, whilst being free in the decision to lie or to tell the truth. As part of the card game’s cover story, participants earned points when the computer they played accepted the deceptive claims or challenged the truthful ones. Due to a balanced distribution of rewarded and unrewarded trials, participants’ response patterns were balanced regarding truth telling and lying.

For our study, we based a novel design on Kireev et al.’s (2013) experimental paradigm as well as Sip et al.’s (2008) proposals. The goal of the design process was to combine PWI task, free decision to lie and potential confrontation in a realistic setting. Hence, we embedded the PWI task in a fictional card game: The PWI stimuli consisting of objects and distracter words were displayed on the cards used in the game. To make sure a lie is related to the distracter word on display, we had to limit the amount of possible lies to a single one. Hence, each trial consisted of a binary choice, tell the truth (target object) or tell a lie (associated object). As part of the card game's cover story we used cards depicting the picture-word stimuli.

The idea behind the game is simple: Two participants were instructed to play a novel card game together. One person played the active part, and the other person played the passive part. The participants played the game with object pairs, which were displayed on playing cards. Each pair was composed of a winning trump object card and one losing object card. In each trial, the active participant saw one of the two cards, either the trump or the losing card, and was instructed to tell the interlocutor the name of the object on the drawn card. The active person won a trial if they claimed to have a trump card and the interlocutor believed them. If the interlocutor did not believe a statement, they could confront the deceiver about their responses and flip over the card to detect deception. The active participant was not instructed when to tell the truth and when to tell the lie. Rather, we varied the incentive to lie or tell the truth trial by trial and punished detected lies: As the active participant won trials by successfully claiming to have a trump card, they needed to tell a lie when they saw a losing card and wanted to win. Thus, we created a scenario, in which we expected participants to always lie in case of drawing a losing card. To rule out a strategy of lying only, detected lies were punished with a subtraction of 3 points from the score. Yet, in rewarded trials participants could win 5 points, which outweighed the potential negative consequences of getting caught. Hence, participants were incentivised to lie when they saw a losing card in a rewarded trial. As lie frequency can be increased by reward (e.g. Shalvi, Eldar & Bereby, 2012; Kouchaki & Smith, 2014), we hypothesized that participants would tell more lies when a trial is rewarded and they see a losing card. In the remaining trials, we incentivised participants to tell the truth: either participants saw a trump card, which guaranteed them a reward, or participants saw a losing card and the trial was unrewarded. In these trials, there was no reason to risk being caught lying. Therefore, we hypothesized that participants would tell the truth in the trials in which there was no reward to lie, or when they already saw a winning trump card.

To analyse our data we used linear mixed models (LMM). This analysis method is advantageous to the, in speech production research most frequently used, ANOVA approach in many ways. One example is that in speech production research, it occurs often that trials cannot be used in the analysis due to issues with voice-key RT recording. The resulting unequal numbers of observations per participants is problematic in the light of the assumptions ANOVAs make, namely that every participant's average has the same weight in all conditions. Since LMMs consider this limitation of ANOVAs, we believed that LMMs would be the superior method to analyse our data. Yet, when analysing data with linear mixed models (LMM), very unequal sample sizes can affect the homogeneity of variance assumption (e.g. Nobre & Singer, 2007). Thus, we adjusted our reward scheme to obtain an even distribution of truthful object naming and deceptive naming. Hence, we incentivised lying in half of the total trials, and incentivised participants to tell the truth in the other half (see Table 1). This means in half of the trials we displayed losing cards with reward and in the other half, either a trump card with reward or a losing card with no reward were displayed. Therefore we hypothesized that participants would tell lies in 50% of all trials and tell the truth in the other half of the trials.

As previously mentioned, we used the classic PWI task, to test the hypothesis that phonological nodes related to the truth are co-activated during phonological encoding of a lie. With the PWI task, we were able to manipulate the phonological encoding during lying by using phonologically related distracter words. When the active participant saw a card in the game, it entailed an object as well as phonological distracter words next to it. In line with studies on phonologically co-active non-target word forms (Jescheniak & Schriefers, 1998), we posited that if the truth is indeed co-active at word form level during lying, the presentation of a phonologically truth-related word during object naming should increase the activation of the truth-related word form. As a result, phonological encoding of the target phoneme should be delayed, which leads to prolonged naming times. Therefore, we hypothesized that indirect, truth-related, distracters lead to slower lying.

Previous research suggests that telling the truth only requires one step: the activation of the truth response (e.g. Debey et al., 2014). In light of this assumption, it seems unlikely that a lie is ever generated when telling the truth. In conclusion, it is improbable that a lie is co-activated during truthful speech production. Therefore, we hypothesized that there is no co-activation of indirect, lie related, distracters when telling the truth. Hence, the truthful object naming times in the presence of indirect distracters should not have differed from naming with unrelated distracters on display.

Contrary to the effect of indirect distracters, distracters which are directly related to the target utterance, increase the activation on the phonological nodes of the target (Melinger & Abdel Rahman, 2004). Thus object naming times in the presence of phonologically direct distracters are usually faster (phonological facilitation effect; e.g. Lupker, 1982). There is no evidence that language production during lying encompasses different steps than truthful language production. Thus, we expect to find an effect of phonological facilitation by direct distracters compared to unrelated distracters, irrespective of the truthfulness of the utterance. The phonological facilitation effect is a good indicator if the used distracter words have an effect on naming times at all.

Methods

Participants

41 participants were recruited for the experiment. For each session two participants were invited. Only the active participants' behaviour was analysed, as they were performing the PWI task. Data from 17 participants had to be excluded from the analysis, as they had used strategies of either telling considerably more lies than truthful messages or vice versa. The remaining twenty-four active participants in the analysis (7 male and 17 female) had a mean age of 25.75 years (SD = 9.71) with a range of 18-65 years. Task partners were naïve participants in 83.33% of these sessions. In the other sessions, the partner was a confederate since the second participant had cancelled the session or did not show. All the participants were recruited from the Psychologischer Experimental-Server Adlershof (PESA) run by the Humboldt-Universität zu Berlin. They all gave informed consent and were compensated with €8 per hour or received credit towards their curriculum requirements.

Materials

Target pictures were 96 black and white line drawings of different objects. The objects were equally divided into 48 two-object pairs (e.g. salmon – hammer). The 48 object pairs were stemming from 12 semantic categories (marine animals, tools, insects, garments, vegetables, conveyances, fruits, weapons, mammals, furniture, birds, musical instruments), which were split into 6 category pairs, so that each pair consisted of one animate category member and one inanimate category member (e.g. marine animals – tools; see Appendix). The animated objects names did not differ from the inanimate objects names in word length ($t(93.99) = -0.80$, $p = 0.42$) nor in their frequency ($t(91.96) = -0.68$, $p = 0.50$) (mean frequencies according to www.dlexdb.de were used).

As the effects of associates on picture naming are very small, we decided to use the double distracter method (Abdel Rahman & Melinger, 2008) to increase the chance of finding the hypothesized effect. For each picture, four distracter word pairs were created: one directly phonologically related pair (DR condition), one indirectly phonologically related pair (IR condition) and two phonologically unrelated pairs. In the direct distracter condition, the distracters were directly related to the participant's utterance. To create the directly related distracter condition, we combined one word sharing at least two initial segments with the target and another word that shared at least two final segments with the target. In the indirect distracter condition, the distracters were related to the associate of the utterance. For the indirectly related distracter conditions, we combined one word that shared initial segments with the associate of the target and another word that shared final segments with the associate (see Appendix). As an example, for truthful naming of the target Lachs [English: salmon] with the associate Zange [English: pliers], the direct distracter pair would be *Lama - Klacks*, and the indirect distracter pair would be *Zahnarzt - Folge*. The directly & indirectly related distracters were reassigned to new pictures to create the unrelated condition (unrelated distracters: *Kader Flipper*, Naming: LACHS). Thus, in the unrelated condition, the word pairs have their initial- and end-segmental overlap with other pictures within the experiment. Since the direct distracters and the indirect distracters were drawn from two different lists, we also created two different lists of unrelated distracters (unrelated direct distracters = DU–Distracters; unrelated indirect distracters = IU–Distracters). To avoid the rejection of every trial in which participants did not answer as expected due to the rewards (telling the truth or a lie), we ultimately assigned the trials to the direct and indirect conditions post-hoc, based on the relation of the distracter word and the object (direct & indirect) and the information whether the object on the card was named (yes or no): For example, when the truth was told (i.e. object on card was named), every trial was assigned to the category of the distracter word on the card (e.g. object and word directly related, participants tells the truth → direct condition). On the other hand, when the lie was told (i.e. associated object was named), then a trial was assigned to the opposite category of the object and distracter condition (e.g. object and word directly related, participants lies → indirect condition). For an illustration of the different conditions please see Figure 2.

Figure 1. Stimulus example. Picture-word interference stimulus fitted onto card silhouette.

The stimuli were displayed at a vertical visual angle of 4.99° and 4.99° horizontally. The distracter words were presented in red and were arranged above one another. The position of the distracter word with the initial segmental overlap (either top or bottom) was randomized across all participants. Relative to the picture, the distracters were placed manually to have a maximal integration in the picture without obscuring the visibility of the picture. The position of the distracter words relative to the object (either bottom-left, top-left, top-right, bottom-right or in the centre) was balanced out across all pictures. Hereby we tried to avoid effects of selective spatial attention in order to maximize distracter effects. For a given picture, word position remained constant across experimental conditions. To maintain the card game cover story the

PWI stimuli were presented on a playing card shape with a white background (example in Figure 1.). The playing cards were presented at vertical visual angle of 10.18° and 7.03° horizontally on a white screen.

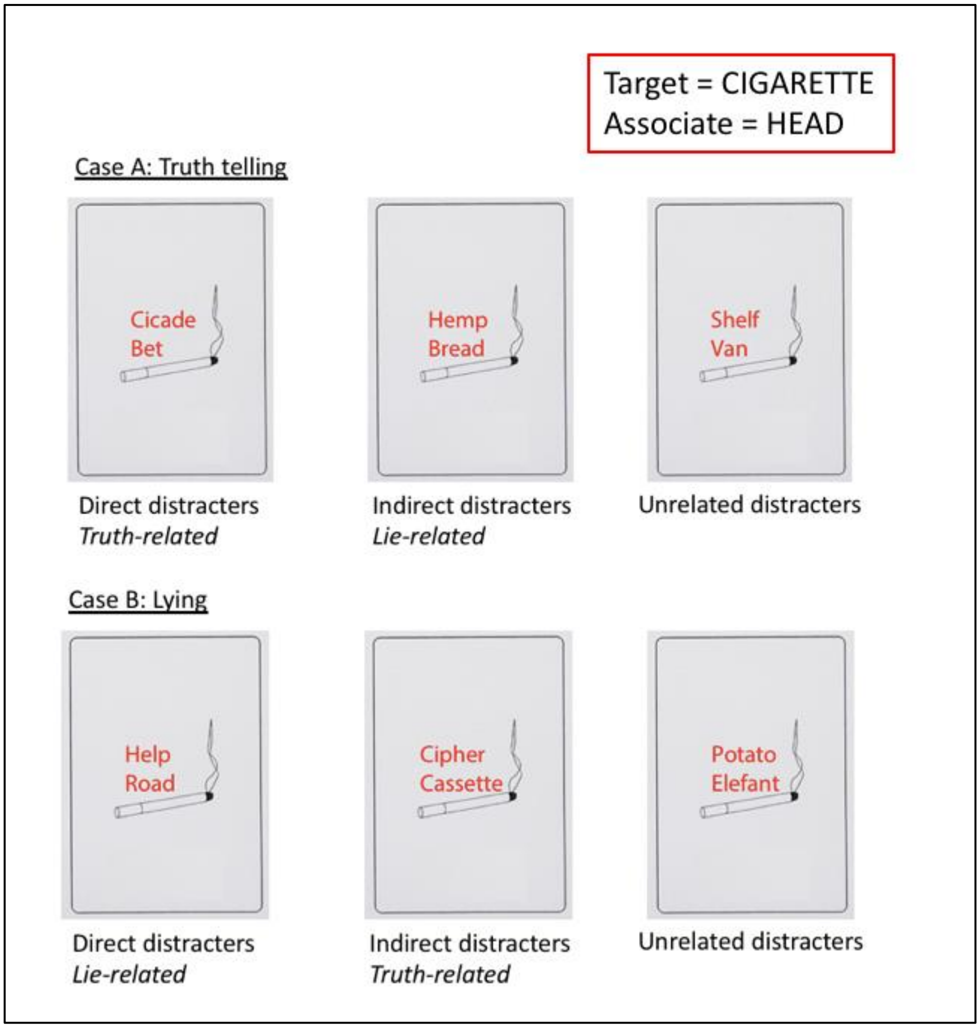

Figure 2. Illustration of the different distracter conditions sharing segments with the target or the associates names, in the case of seeing the target "cigarette" with the associate "head". In case of truth telling, truth-related distracters are direct distracters and lie-related distracters are indirect distracters. In case of lying, lie-related distracters are direct distracters and truth-related distracters are indirect distracters.

Apparatus

Both participants were seated opposite to each other. Each participant faced a monitor on which the stimuli were presented on a white background. The participants sat at a distance of 70cm to their screens. The monitors were positioned at eye level to avoid eye contact between the participants. Stimulus presentation and response recording was controlled using Presentation software (Version 0.70, www.neurobs.com). The participants' naming responses were measured with a voice-key. Participants were instructed to name the pictures as quickly and accurately as possible and to ignore the distractors.

Task and Procedure

At the beginning of each session, the two participants were assigned a role by the experimenter (active participant or interlocutor). Once assigned, the roles remained unchanged during the entire experiment. Since only the active participants executed the actual object naming, only their RTs were recorded and analysed. After being seated, both participants received instructions on their screens, followed by a practice block containing random objects and random distracter words, which were all unrelated and none of the stimuli appeared in the main experiment. Subsequently the actual experiment started (An illustration of the task is provided in Figure 3.).

In the beginning of the main experimental session, the participants were familiarized with the two object pairs (a pair consisting of one trump and one losing card) and the corresponding object names, which would be on the cards in the upcoming pair block (16 trials in random order). During familiarization, a red rectangle framed the trump object of each pair. To assure correct naming the participants were instructed to continue only when they were certain they could remember the objects and their associates, which would appear in the upcoming pair block.

To signal they were ready to continue, both participants had a button in front of them. Each trial began with the presentation of a fixation cross on the screen of both participants for a duration of 500ms. Next, information about the reward of the trial (either 5 or 0 points) was presented to both participants (1500ms). Then, the PWI stimulus was presented to the active participant, who named the object on the card. At the same time, only the back of the card was shown to the interlocutor. After naming, the stimuli of both participants disappeared. The naming was followed by the experimenter coding any failure of the voice-key (onset too early) as well as erroneous trials (object named incorrectly, wrong object named or by the wrong person). During response coding, the participants saw a fixation cross on their screens, which disappeared when the answer had been coded by the experimenter. Next, the interlocutor had the chance to disclose a possible attempt of deception by the active participant (“aufdecken”; “glaub ich!”; English: *flip over; believe it!*). The response to this question was indicated using keys on the table corresponding to “yes” or “no”. During the decision time of the opponent, the active participant saw a “?” on the screen. If the interlocutor did not challenge the response, the experiment continued with the next trial. If the interlocutor challenged the response, the previous card was displayed on both participants’ screens with a blue frame for 3000ms. In this case, the interlocutor was able to check if the previous response had been a lie and active participants saw when their response had been challenged.

The experiment as a whole was split into six big category blocks of 64 trials. Each big category block contained objects from two categories which were presented as a category pair (e.g. sea animal – tools). Participants were informed about the categories of each upcoming big category block at its beginning. As with objects, a red rectangle framed the category, which would be the trump category of the category block. Each category block respectively was separated into four pair block segments of 16 trials, unfolding as previously described. In between each big category block, participants could take a self-paced break before memorizing the next objects.

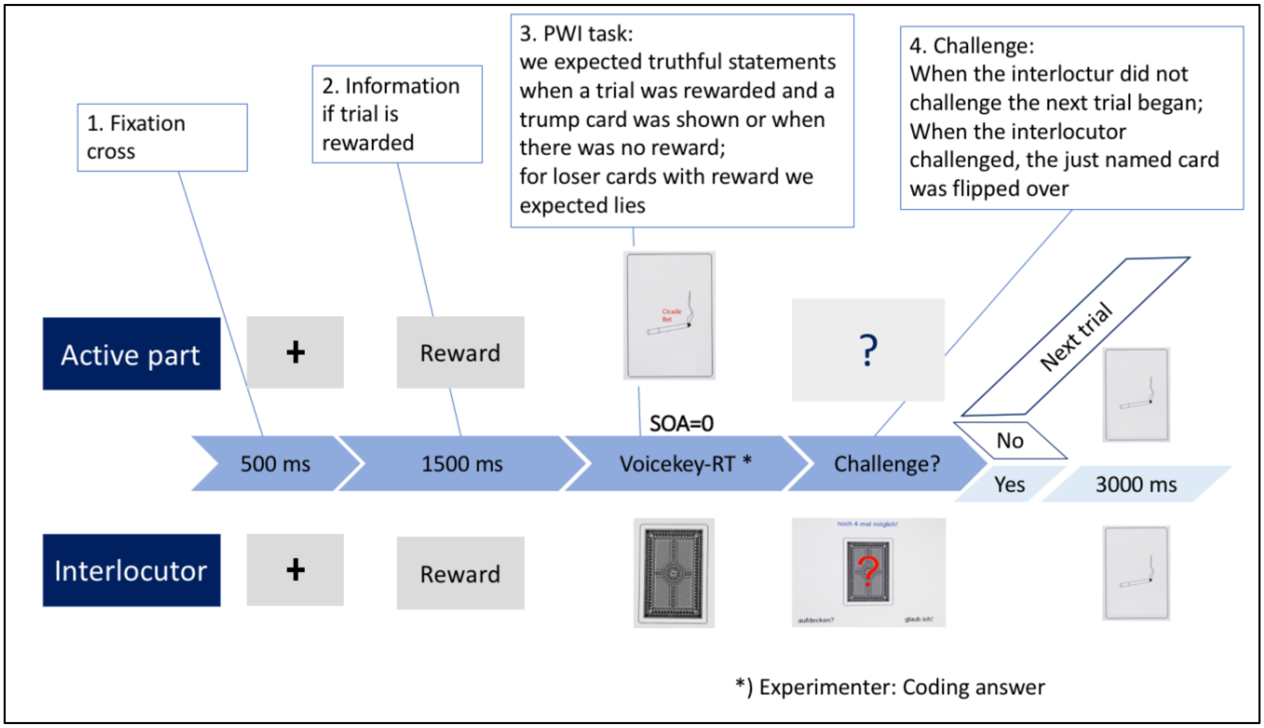

Figure 3. Trial schematic. After a 500 ms fixation cross, both participants were informed whether the upcoming trial is rewarded or not. Next, the PWI task was carried out by the active participants after which the interlocutor could challenge the response.

To avoid that participants choose a strategy of lying only, we instances in which lying was detected were punished: If the active participants were caught lying, 3 points were subtracted from their score. If the challenged response had been a truthful response, no points were added or subtracted from the score. To keep the active participants incentivised to lie, the number of possible challenges that the interlocutor could make was limited. Hence, it was not possible for interlocutors to challenge statements in every trial. Once the contingent was depleted, the interlocutor could only continue in the experiment by pressing the yes button until it was replenished after each completed big category block. In order to conceal the level of the contingent to the active participant, the volume of the contingent varied randomly with an average of 12 times/64 trials (range 8 -14). Due to the number of challenges varying from category block to category block, it was difficult for the active participants to track the interlocutor’s contingent, allowing them to focus on the decision whether to be honest or not. This was important to ensure that participants were attentive in all conditions and did not constantly lie once the contingent of a block was emptied. Hereby we avoided that participants could prepare a response before seeing the stimulus, since lying could not be punished anymore.

To steer the response patterns without instructing deceptive behaviour, we varied the incentive to lie from trial to trial: the victory of each experimental trial was either rewarded with 5 points or 0 points. Thus, in some trials there was an incentive to lie and in some there was not. The active participants won a trial in those cases when the interlocutor “accepted” a deceptive claim or active participants truthfully named a trump card. Being caught lying was always punished with the subtraction of 3 points from the total score. This way, participants were incentivised to tell the truth when telling a lie was not incentivised. To obtain a balance of truthful and deceptive responses, out of the sixteen trials, 12 were rewarded with 5 points and 4 trials were unrewarded. Since 4 of the rewarded trials were winning trump cards, we expected honest responses in these trials as well as in the 4 unrewarded trials (cf. Table 1). In order to keep the participants’ focus on the task, the participants were not able to track their rewards on a trial by trial basis. Instead at the end of each big category block, the active participant could see their score on the screen for 3000 ms. Hereby, participants still received feedback about their performance and could adjust their response patterns to maximise reward.

In total, each session consisted of 384 trials, and including self-paced breaks between the category blocks, the duration of the entire experiment was 60-90 minutes, varying according to the speed of the individual participants. The order of the big category blocks was randomized separately for each participant as well as the item order within each category block. Overall, including all 24 participants, 2304 stimuli were trump cards (with 1152 direct distracters and 1152 unrelated distracters) and 6912 trials were losing cards (with 1152 direct, 2304 indirect and 3456 unrelated distracters) (Table 1). In the experiment, the card type of an object (e.g. penguin being a trump) was balanced across participants. Furthermore, we balanced the position of the initial overlap of the distracter words (i.e. if the initial segmental overlap is the distracter word is on the top or the bottom) across participants. In conclusion, the experiment was counter-balanced according to a 2 (card type [trump card vs. losing card]) x 2 (position of initial overlap [top vs. bottom]) design.

Analysis

Only correct naming trials with response times between 300 and 3000 ms were included in the analysis. All trials including incorrect or disfluent naming, technical errors, or the voice-key errors were discarded. Further, trials in which participants saw a trump card and told a lie were excluded from the analysis as well, as these answers are irrational in the sense that participants rejected a reward whilst they risked getting caught. As this behaviour is highly irrational, it is difficult to interpret these trials, wherefore we decided to exclude these trials from the analysis. In total, 92.07% of all trials were analysed. All RT analyses were performed on the log-transformed naming latencies.

Data were analysed with linear mixed effects models (LMM; Baayen, Davidson, & Bates, 2008) and generalized linear mixed models (GLMM) as implemented in the lmer function of the lme4 package (Bates, Mächler, Bolker, & Walker, 2014) for R-Studio (Version 1.1.383; R Core Team, 2017). To analyse effects of the different card types (losing card vs. trump card) and of reward (no vs. yes) on the naming decision (truth vs. lie), we ran a GLMM analysis, fitting a binomial model (Bolker, 2008). For the GLMM analysis, we modelled naming (truth vs. lie) as a dependent variable with reward, card type and position of initial overlap (bottom vs. top) as fixed effects. As random effects we modelled random intercepts for participants and objects.

To analyse naming times as the dependent variable, we conducted a LMM analysis with random intercepts for participants and objects. The naming latencies were modelled as a function of naming (truth vs. lie) and distracter (unrelated direct distracters vs. related direct distracters; related indirect distracters vs. unrelated direct distracters; unrelated indirect distracters vs. related indirect distracters), position of initial overlap (bottom vs. top) and reward (no vs. yes), plus card type (trump card vs. losing card) as fixed effects. Further, to investigate if the unrelated distracter conditions differ (DU and IU), we split the four-level factor distracter into two factors with two levels: distracter directness (indirect vs. direct) and distracter relatedness (related vs. unrelated). This way we are able to analyse the effects of unrelated distracters, which were split in the previous model. We then modelled naming latencies in an LMM analysis as a function of naming, distracter relatedness, distracter directness, and position of initial overlap, as well as card type (trump card vs. losing card) as fixed factors. As random effects, we modelled participants and objects.

For all predictors, we applied sliding difference contrasts, which compare subsequent factor levels (level 2 minus level 1, e.g. lie - truth). For fixed effects, we will report fixed effect estimates, standard errors (*SE*), *t*-values and *p*-values, as well as the estimates of variance and the square root (standard deviations) of the random effect structure, and goodness-of-fit statistics. All the reported *p*-values were computed with the lmerTest package, using Satterthwaite approximation for degrees of freedom. To interpret these values, we used an alpha level of .05 for all statistical tests.

To investigate the effect of naming, we decided post-hoc to run a one sided *t*-test with an alpha-level of .05.

Unlike in other PWI experiments, we ultimately assigned the trials to the direct and indirect conditions post-hoc, based on the relation of the distracter word and the object (direct & indirect) and the information whether the object on the card was named (yes or no). To test if this approach of analysis influenced the obtained results, we conducted a further post-hoc LMM analysis, which only considered the trials in which participants acted as predicted based on reward and card type. In these cases, the stimulus-utterance relationship could have been determined before the experiment.

Results

Analysis of the design and its effect on the response patterns

In order to examine naming decisions, telling the truth or lying, as a dependent variable, we computed a GLMM analysis with reward, card type and position of initial overlap as fixed effects and random intercepts for participants and objects. The participants deceived more often when there was a reward for the trial, which was confirmed by a main effect of reward on the decision to deceive ($b = 1.73$, $SE = 0.22$, $p < .001$; see also Table 2). Neither card type ($b = -20.51$, $SE = 62.97$, $p = .744$), nor the position of the initial overlap significantly affected naming decisions ($b = -0.18$, $SE = 0.23$, $p = .435$).

An overview of the mean naming latencies can be found in Table 3. Naming latencies as a dependent variable were modelled in a LMM analysis, with the predictors distracter condition, reward, position of initial overlap and card type. This analysis unveiled a significant main effect of reward: naming times in rewarded trials were slower than in unrewarded trials (b = 0.11, SE < 0.01, p < .001; see also Table 4). This effect of reward interacted with naming (b = -0.08, SE = 0.02, p < .001). To follow up on this interaction we computed nested models (see Table 5). Those models unveiled that rewarded trials were named slower than trials without a reward both when telling the truth (b = 0.15, SE = 0.01, p < .001), as well as when lying (b = 0.07, SE = 0.01, p < .001).

Table 2

Effects of Reward, Card type and Position of initial overlap on the decision to tell the truth or to lie

Model structure:					
Naming ~ position of initial overlap + reward + card type +(reward + card type | participant) + (reward + card type | object)					
Fixed effects	Estimate	*SE*	*z*-value	*p*-value	
Intercept	-10.13	31.48	-0.32	.748	
Reward	1.73	0.22	7.88	< .001	***
Card type	-20.52	62.97	-0.33	.744	
Position of initial overlap	-0.18	0.23	-0.78	.435	

Variance components	Variance	*SD*	*Goodness of fit*	
Participants			Log likelihood	-3709.8
Intercept	0.19	0.43	REML deviance	7419.6
Reward	1.02	1.01		
Card type	0.51	0.71		
Object				
Intercept	< 0.01	0.04		
Reward	0.15	0.39		
Card type	0.10	0.32		

Note: Reward = no – yes, Card type = trump card – losing card, Position of initial overlap = bottom – top;
*** p < .001, ** p < .01, * p < .05

Furthermore, participants were faster to name an object when they named a trump card compared to naming a losing card, this difference was confirmed in the LMM analysis with the predictors distracter condition, reward, position of initial overlap and card type. The analysis unveiled a main effect of card type on naming latencies: (b = -0.16, SE = 0.01, p < .001; see

Table 4). As trials in which participants lied when they saw trump cards were excluded from the analysis, this effect is specific to truth telling.

The overall answer patterns were as predicted, insofar as lying and truth telling were evenly distributed across trials and distracter condition. We observed 20 trials of truth and deception within each distracter condition for every single participant at minimum.

Table 3

*Number of trials per condition (N), Mean reaction times (RT, in milliseconds), Standard Errors (*SE*) and Effect sizes (Cohen's* d)

Distracter condition	N	RT	*SE*	*d*
Naming: Truth				
Direct distracters				
Related	1362	981.88	9.03	
unrelated	1352	1006.33	9.26	-0.10
Indirect distracters				
related	1008	1102.68	12.15	
unrelated	1029	1059.08	12.77	0.11
Naming: Lying				
Direct distracters				
related	1126	1016.24	10.60	
unrelated	1114	1099.82	12.32	-0.22
Indirect distracters				
related	742	1073.28	14.17	
unrelated	752	1056.53	13.27	0.05

Naming latencies of stimuli with direct distracters

In order to test if we succeeded in manipulating naming latencies with phonological distracter words, we analysed the influence of direct distracters on reaction times in an LMM analysis with the predictors distracter condition, reward, position of initial overlap and card type. The data demonstrate that object naming in the presence of directly related distracter is overall faster compared to the unrelated distracter condition. This decrease in naming times appears as a main effect in the LMM analysis (b = 0.05, SE < 0.01, p < .001; see Table 4). In addition to this main effect, the naming times in the direct and unrelated condition interacted with naming (b =

0.05, $SE = 0.02$, $p = .002$). We computed nested models to follow up on this interaction. Those revealed the speed-up of naming times in the direct distracter condition compared with unrelated distracters in the truth condition ($b = 0.02$, $SE = 0.01$, $p = .038$; see Table 5) as well as in the lying condition ($b = 0.08$, $SE = 0.01$, $p < .001$). Thus, we can interpret the main effect such that object naming times when direct distracters were displayed were faster than when unrelated distracters were displayed. This effect is stable across both naming conditions, truthful statements and deceptive statements.

Table 4

Effects of experimental manipulations on naming latencies

Model structure:					
RT ~ naming * (distracter + reward + position of initial overlap) + card type + (naming | subject) + (naming | object)					
Fixed effects	Estimate	*SE*	*t*-value	*p*-value	
Intercept	6.83	0.02	308.76	< .001	***
Naming	-0.05	0.02	-2.74	.009	**
Distracter DU – DR	0.05	< 0.01	5.89	< .001	***
Distracter IR – DU	0.02	0.01	1.75	.079	
Distracter IU – IR	-0.03	< 0.01	-3.29	< .001	***
Reward	0.11	< 0.01	11.32	< .001	***
Position of initial overlap	0.07	0.04	1.67	.107	
Card type	-0.16	0.01	-11.81	< .001	***
Naming x DU – DR	0.05	0.02	3.11	.002	**
Naming x IR – DU	-0.12	0.02	-5.21	< .001	***
Naming x IU – IR	0.05	0.02	2.52	.012	*
Naming x Reward	-0.08	0.02	-4.21	< .001	***
Naming x Position of initial overlap	0.01	0.03	0.46	.648	

Variance components	Variance	*SD*	*Goodness of fit*	
Participants			Log likelihood	-1662.8
Intercept	0.01	0.10	REML deviance	3325.6
Naming	< 0.01	0.07		
Object				
Intercept	< 0.01	0.04		
Naming	< 0.01	0.03		
Residual	0.08	0.29		

Note: Naming = lie – truth, Card type = trump – losing card, DU = Direct Unrelated, DR = Direct Related, IR= Indirect Related, IU = Indirect Unrelated, Position of initial overlap = bottom – top, Reward = no – yes; *** $p < .001$, ** $p < .01$, * $p < .05$

Naming latencies of stimuli with indirectly related distracters

With the same models we used to analyse effects of direct distracters, we investigated the effects of indirect distracters (see Table 4) The models unveiled a significant main effect of indirect distracters on naming times, with increased naming times for indirect distracters compared to unrelated distracters (b = -0.03, SE < 0.01, p < .001). We also observed an interaction of naming and indirect distracters (b = 0.05 SE = 0.02, p = .012). To determine the nature of this interaction we computed nested models. The nested models revealed that only when the participants named the stimuli truthfully, indirect distracters slowed naming times (b = -0.06, SE = 0.01, p < .001; see Table 5). In other words, we could observe here that lie-related distracters slowed truth telling. When participants lied about the identity of the stimuli, indirect distracters had no effect on naming times (b < -0.01, SE = 0.02, p = .613). Thus, when participants told the truth, they were slower to do so in the presence of lie-related distracters than with unrelated distracters on display. When participants lied, truth-related distracters did not affect naming times in comparison to unrelated distracters.

Naming latencies of stimuli with unrelated distracters

In a subsequent analysis, we investigated if the distracter words we used in the experiment influenced naming times even when presented with unrelated objects. To do so, we compared both word lists in their unrelated conditions (DU vs. IU). To unravel the effects of unrelated distracters, we split the four-level-factor distracter into the two factors distracters directness and distracter relatedness. The LMM analysis with the predictors distracter directness, naming, reward, position of initial overlap and card type (see Table 6) revealed slower naming times of the unrelated direct distracters in comparison to the unrelated direct distracters (b = -0.05, SE = 0.01, p < .001).

Table 5

Effects of experimental manipulations on naming latencies

Model structure:					
RT ~ naming / (distracter + position of initial overlap + reward) + card type + (naming | participant) + (naming | object)					
Fixed effects	Estimate	*SE*	*t*-value	*p*-value	
Intercept	6.83	0.02	308.76	< .001	***
Naming	-0.05	0.02	-2.74	.009	**
Card type	-0.16	0.01	-11.81	< .001	***
Truth x Distracter DU – DR	0.02	0.01	2.07	.038	*
Lie x Distracter DU – DR	0.08	0.01	6.08	< .001	***
Truth x Distracter IR – DU	0.08	0.02	4.40	< .001	***
Lie x Distracter IR – DU	-0.04	0.02	-2.82	.005	**
Truth x Distracter IU – IR	-0.06	0.01	-4.47	< .001	***
Lie x Distracter IU – IR	< -0.01	0.02	-0.51	.613	
Truth x Position of initial overlap	0.06	0.04	1.56	.133	
Lie x Position of initial overlap	0.08	0.05	1.61	.122	
Truth x Reward	0.15	0.01	10.62	< .001	***
Lie x Reward	0.07	0.01	5.18	< .001	***

Variance components	Variance	*SD*	*Goodness of fit*	
Participants			Log-likelihood	-1662.8
Intercept	0.01	0.10	REML deviance	3325.6
Naming	< 0.01	0.07		
Object				
Intercept	< 0.01	0.04		
Naming	< 0.01	0.03		
Residual	0.08	0.29		

Note: Naming = lie – truth, Card type = trump – losing card, DU = Direct Unrelated, DR = Direct Related, IR= Indirect Related, IU = Indirect Unrelated, Position of initial overlap = bottom – top, Reward = no – yes; *** $p < .001$, ** $p < .01$, * $p < .05$

Table 6

Effects of experimental manipulations on naming latencies

Model structure:					
RT ~ distracter relatedness / (distracter directness + naming + reward + position of initial overlap) + card type + (naming | participant) + (naming | object)					
Fixed effects	Estimate	*SE*	*t*-value	*p*-value	
Intercept	6.83	0.02	307.47	< .001	***
Distracter relatedness	-0.02	< 0.01	-2.01	.044	*
Card type	-0.18	0.01	-15.63	< .001	***
Unrelated distracter x Distracter relatedness	-0.05	0.01	-4.33	< .001	***
Related distracter x Distracter relatedness	0.04	0.01	4.15	< .001	***
Unrelated distracter x Naming	-0.04	0.02	-2.39	.021	*
Related distracters x Naming	-0.10	0.02	-5.43	< .001	***
Unrelated distracter x Reward	0.08	0.01	7.05	< .001	***
Related distracters x Reward	0.11	0.01	9.41	< .001	***
Unrelated distracters x Position of initial overlap	0.07	0.04	1.67	.107	
Related distracters x Position of initial overlap	0.06	0.04	1.54	.135	

Variance components	Variance	*SD*	*Goodness of fit*	
Participants			Log likelihood	-1674.1
Intercept	0.01	0.10	REML deviance	3348.1
Naming	< 0.01	0.07		
Object				
Intercept	< 0.01	0.04		
Naming	< 0.01	0.03		
Residual	0.08	0.29		

Note: Card type = trump card – losing card, Distracter relatedness = indirect distracter – direct distracters, Naming = lie – truth, Reward = no – yes, Position of initial overlap = bottom – top; *** $p < .001$, ** $p < .01$, * $p < .05$

The effects of truth telling and lying on reaction times

In average, truth telling (1031.19 ms; *SD* = 486.88) was faster than lying (1060.63 ms; *SD* = 505.59). A post-hoc *t*-test unveiled that this difference is significant ($t(7871.4) = -2.71$, $p = .003$). In a previous LMM analysis we saw that this effect interacts with the distracters conditions: truth telling is faster than lying with direct distracters on display and vice versa with indirect distracters (see Table 4). This means that truth telling in the presence of lie-related distracters was slower than lying in the presence of truth-related distracters.

Table 7

Effects of experimental manipulations with only trials in which responses were as predicted in analysis

Model structure:					
RT ~ naming * (distracter + reward + position of initial overlap) + card type + (naming | subject) + (naming | object)					
Fixed effects	Estimate	*SE*	*t*-value	*p*-value	
Intercept	6.92	0.02	305.36	< .001	***
Naming	0.13	0.02	6.16	< .001	***
Distracter DU – DR	0.03	< 0.01	2.76	.006	**
Distracter IR – DU	-0.02	0.02	-1.31	.258	
Distracter IU – IR	-0.04	0.01	-4.11	< .001	***
Reward	-0.12	0.02	-5.62	< .001	***
Position of initial overlap	0.07	0.04	1.68	.107	
Naming x DU – DR	< -0.01	0.02	< -0.01	.992	
Naming x IR – DU	0.07	0.02	3.41	< .001	***
Naming x Position of initial overlap	0.01	0.04	0.31	.758	

Variance components	Variance	*SD*		*Goodness of fit*	
Participants				Log likelihood	-1207.3
Intercept	0.01	0.10		REML deviance	2414.6
Naming	< 0.01	0.08			
Object					
Intercept	< 0.01	0.05			
Naming	< 0.01	0.03			
Residual	0.08	0.29			

Note: Naming = lie – truth, Card type = trump – losing card, DU = Direct Unrelated, DR = Direct Related, IR= Indirect Related, IU = Indirect Unrelated, Position of initial overlap = bottom – top, Reward = no – yes; *** $p < .001$, ** $p < .01$, * $p < .05$

Table 8

Nested models with only trials in which responses were as predicted in analysis

Model structure:					
RT ~ naming / (distracter + position of initial overlap + reward) + card type + (naming | participant) + (naming | object)					
Fixed effects	Estimate	*SE*	*t*-value	*p*-value	
Intercept	6.86	0.02	308.71	< .001	***
Naming	0.02	0.02	0.98	.334	
Card type	-0.10	0.01	-7.01	< .001	***
Truth x Distracter DU – DR	0.03	0.01	2.14	.032	*
Lie x Distracter DU – DR	0.03	0.02	1.80	.072	
Lie x Distracter IR – DU	-0.02	0.02	-1.13	.258	
Truth x Distracter IU – IR	-0.08	0.02	-5.25	< .001	***
Lie x Distracter IU – IR	-0.07	0.02	-0.50	.616	
Truth x Position of initial overlap	0.07	0.04	1.57	.130	
Lie x Position of initial overlap	0.08	0.05	1.55	.135	

Variance components	Variance	*SD*	*Goodness of fit*	
Participants			Log likelihood	-1207.3
Intercept	0.01	0.10	REML deviance	2414.6
Naming	< 0.01	0.08		
Object				
Intercept	< 0.01	0.05		
Naming	< 0.01	0.03		
Residual	0.08	0.29		

Note: Naming = lie – truth, Card type = trump – losing card, DU = Direct Unrelated, DR = Direct Related, IR= Indirect Related, IU = Indirect Unrelated, Position of initial overlap = bottom – top, Reward = no – yes; *** $p < .001$, ** $p < .01$, * $p < .05$

Credibility check: Test of post-experimental assignation to conditions

To investigate if reassigning the trials to their conditions post-hoc affected results, we ran an LMM analysis, in which we tested if we observe similar results as we have when we only consider the trials in which participants acted as predicted based on reward and card type. After omitting all trials in which participants answered differently than predicted, 6511 trials were left in the analysis, compared to a total of 8485 in the main analysis. The LMM analysis with the predictors distracter condition, reward, position of initial overlap and card type revealed similar main effects as the main analysis, as can be seen in Table 7 (cf. Table 4, same models for 8485 trials). The analysis unveiled significant main effects of naming (b = 0.13, SE = 0.02, p < .001), direct distracters (b = 0.03, SE < 0.01, p = .006), indirect distracters (b = -0.04, SE = 0.01, p < .001), reward (b = -0.12, SE = 0.02, p < .001) and an interaction of naming and indirect distracters (b = 0.07, SE = 0.02, p < .001). To further investigate the observed interactions, we computed nested models, which revealed similar results as the nested models in the main analysis (Table 8, cf. Table 5, same models for 8485 trials), with only the main effect of naming and the facilitation effect of direct distracters when telling a lie not being significant compared to the main analysis with 8485 trials in the analysis.

Discussion

The activation of the truth has often been considered relevant in the act of lying (e.g. Spence et al., 2001; Walczyk et al., 2014). Yet, its role for deception production is debated. The fact that the truth might be co-activated during language production has been largely ignored. Because measures of verbal efficiency predict prolonged deception production times (Walczyk et al., 2003), we proposed that the co-activated truth might interfere with speech production, more specifically phonological encoding, during lying. If the truth is activated at word form level, the presentation of phonologically truth-related distracter words may cause an even stronger activation of its phoneme. As a result, phonological encoding should be delayed which would be reflected in longer RTs.

The current study therefore examined the effects of truth related distracters on deception production times. To investigate the course of co-activation we constructed a new experimental design, which embeds a PWI task into a social context that encourages deception. Two participants played a fictional card game against each other. At the heart of the game was a PWI task during which the deceiving participants made honest and dishonest claims about the objects they had seen. As predicted, when participants were rewarded they were more likely to deceive than they were without reward. Further participants lied more when they saw a losing card than when they were presented a trump card. Hence, we could demonstrate that it is possible to obtain a sufficient amount of trials in each condition in a PWI experiment without instructing deception explicitly. In addition to this, we could replicate the well-established phonological facilitation effect with faster naming times for direct distracters compared to unrelated ones. As predicted, the effect was found when participants said the truth as well as when they lied. Indirect distracters, contrary to our predictions, only slowed naming for truthful naming and had no effect on naming times at all when participants lied. Hence phonological truth-related distracters did not affect lying, but lie-related distracters did affect truth telling. The implications of these results will be discussed further in this section.

Implications of the presented results

First of all, the results we obtained show that the participants' response behaviour could be effectively manipulated by the card game cover story: As predicted, when participants were rewarded to tell a lie, they were also more likely to do so (in Table 9 you can see an overview of observed answer types; cf. Table 1). Overall, participants told the truth in 55.99% of all trials and told a lie in 44.01% of the trials respectively. Thus, for each distracter condition we collected at least 20 trials per participant, which we could use in the analysis. This confirms that the experimental setup is incentivises the participants sufficiently to lie for instructed deception to be obsolete. We can conclude that we found a way to make participants lie in a standardised experimental setup. Given that instructed deception is less valid and thus probably does not depict the production of a lie accurately (Sip et al., 2012), it is good news that we managed to design an experimental setting that abdicates instructed lies.

To avoid the rejection of every trial in which participants did not answer as expected due to the rewards (telling the truth or a lie), we ultimately assigned the trials to the direct and indirect conditions post-hoc, based on the relation of the distracter word and the object (direct & indirect) and the information regarding whether the object on the card was named (yes or no). This approach is quite unorthodox and not practised in the PWI literature. Therefore, we ran an additional analysis, in which we tested if we would obtain the same results as we had, when we only considered the trials in which participants acted as predicted based on reward and card type (6511 trials, compared to a total of 8485 in the normal analysis). In these cases, the stimulus-utterance relationship can be determined before the experiment. The analysis revealed that the results pattern we observed is similar to the one we report in our results section. The effects of the distracter words we reported are similar, all going in the same direction as in the main analysis. Only the phonological facilitation effect failed to be significant in the truth telling condition, which can probably be attributed to the reduced number of trials (p = .072). Hence, we can confirm that the post-hoc assignation of trials to the direct and indirect categories did not alter the observed distracter effects (compare results in Table 4 and 5 with Table 7 and 8). Although the main effect of naming (truth telling or lying) on RTs changed direction in the "credibility check analysis", this circumstance is not limiting to our results. This is because the effect is not significant in the nested models (cf. Table 7 and Table 8), which shows that, just as in our main analysis, the effect is difficult to interpret all along. As no central hypotheses of the current study were linked to this effect we argue that the change of direction of this effect is not limiting the validity of our results. Hence, the fact that the main effect of naming points in a different direction is not a limitation to the reported results in the present study. Furthermore, the effect of reward changed direction in the "credibility check analysis" compared to the main analysis we ran, now unveiling faster naming for rewarded trials. However, the difference between the two analyses' results can be explained by the fact that in the “credibility check analysis” we had omitted all trials in which participants lied without seeing a reward. Therefore the “credibility check analysis” was rank deficient, which renders a valid comparison of lying in the truth and lying condition impossible. Hence, in the “credibility check analysis”, the lying RTs cannot be analysed in a similar way as in the main analysis in regard of the influence of the reward. In sum, the distracter effects and mean RT's are the same when all trails are in the analysis as when only trials in which participants responded as predicted are considered (Figure 4). Therefore, we conclude that the use of this unconventional approach can be further employed in PWI research, especially as it necessitates less exclusion of trials which increases experimental power.

Furthermore, the results confirm the attempted manipulation of speech production by using distracter words, which were related to the truth or the lie. The analysis of naming times in the PWI task unveiled a phonological facilitation effect, which is stable across both lying and truth telling. This is confirming our hypothesis, that phonologically direct distracters reduce naming times. We observed the facilitation effect irrespective of telling the truth or a lie, which is proof that the classic PWI task, as employed in our design, is an apt task to investigate deception. We explain the decreased naming times by the fact that the direct distracters facilitated the phonological encoding of the target utterance, which in turn speeds speech production (cf. Abdel Rahman & Melinger, 2008). Thus, the stimuli used in the experiment were large enough and had enough phonological overlap with the target utterances to affect the process of speech production. Hence, we can rule out that effects went undetected in our experiment due to the used stimulus material. The unexpected interaction of the phonological facilitation effect with the naming conditions is most likely explained by the differing sizes of the effects. Whilst the phonological facilitation in the truth condition had an effect size of $d = -0.10$, the facilitation effect when lying is much larger with a size of $d = -0.22$. This leads to the conclusion, that the current study is the first of its kind that demonstrates a phonological facilitation effect of distracters directly related to the utterance when lying. Demonstrating that distracter words in a PWI task have the same effects when lying as when telling the truth indicates that the stage of phonological encoding plays a similarly crucial role during speech production of deceptive messages as when telling the truth. On the grounds of the demonstrated effectiveness of the PWI task manipulation to investigate lying, we suggest that the reported design thus allows to further investigate the speech production of lying in an ecologically valid setting. We emphasize that the employed PWI task can potentially be of the same utility for future research investigating lying as it is for the investigation of truthful speech production.

Moreover, we find that lie-related distracters affect truth telling RTs. In fact, lie-related, indirect, distracters caused slower reaction times than unrelated distracters. The simplest explanation for the effect of indirect distracters finding would be the set-up of the experiment. To ensure a relation between utterance and the distracter words on the screen, participants had to memorise all the object pairs in the experiment. This way, ad-hoc associates were created. It is possible, that in order to respond quickly, participants always rehearsed the pairs in their head before a stimulus was presented. Hence, in this logic the lemmas of trump and losing objects were activated during the experiment to make quick responding possible. Indirect distracters then might have activated the phonemes of the targets associate and increased the activation of its lemma, respectively. This in turn slows lexical access, which results in increased lexical decision latencies. This might explain why we observed slower naming times with indirect, lie-related, distracters on display when telling the truth. Thus, the mediated semantic interference effect might solely be due to the to-be named objects being memorised in pairs. Yet, if the mediated interference effects were simply due to the experimental set-up, we would predict to find the effect irrespective of lying and truth telling. However, we do not find effects of indirect distracters when participants told a lie. Contrary to our predictions, truth-related distracters did not slow lie naming times. In fact, truth-related distracters did not differ at all from the unrelated distracter condition when lying. Thus, it is unlikely that the interference effect of indirect distracters when telling the truth is simply due to the associated object being active to ensure memory retrieval because then we would have observed the mediated semantic interference effect in both naming conditions. Respective, the absence of an effect of truth-related distracters on lying cannot be explained by the lack of an association between truth and lie. As we could demonstrate an effect of indirect distracters when participants told the truth, we can also rule out that we did not observe an indirect distracter effect in the lying condition because participants failed to remember the object pairs.

In the light of this, it is surprising that we do not find effects of truth-related distracters when participants told a lie. The existence of such indirect distracter effects, which slow naming times compared to unrelated distracters when lying, was the main hypothesis of the current study. Contrary to our predictions, indirect distracters did not differ at all from the unrelated distracter condition. Since the inability to observe an effect is not a proof that the investigated effect does not exist, caution is necessary when interpreting this finding. As we observed an effect of the direct distracters on naming times, it is unlikely that the shape or size of the used stimuli explains the absence of the hypothesized effect in the data. Furthermore, we can also rule out that trump and losing object were not associated well enough to affect speech production as we find an effect of mediated semantic interference of indirect distracters during truth telling. In contrast, it seems much more likely that the absence of the effect might be due to the lie-encouraging setting we created. In real life participants tell about three lies a day (DePaulo et al., 1996). In our experiment on the other hand, about 44% of all utterances were lies. Therefore, we have appear to have created a setting in which lying was by far more prevalent. As a total of about two-thirds of all utterances were the names of trump objects (more than the 45% due to correct naming of the trumps), naming the trump object was the default of the experiment. Hence it might be that in all trials, participants simply pre-activated the two trump objects' names which would win the trial. This account is supported by the fact that trump cards were named the fastest, which is also confirmed by a main effect in the LMM analysis (Table 4). All trials in the analysis, in which the truth was told with lie-related distracters on display, reflect participants seeing a losing card and lying that they see a trump card. Hence, in these cases, the truth related-distracters were always related to losing cards. As the participants probably pre-activated the trump objects-names to obtain a reward, the truth-related answer might have been already prepared insofar that the truth (losing objects name) did not even get processed at word form level. Thus, there was no observable co-activation of the truth at word form level when lying. Concerning effects when truth telling on the other hand, during all trials in the experiment, in which the truth was told and lie-related distracters were presented, losing cards were shown. Thus, the indirect distracters to the losing cards were trump cards. As one would predict, co-active trump card names slowed naming in these cases, because here the co-activated trump response was boosted by the congruent distracter words, which in turn delayed the selection of the truth (losing object's name). This is the effect of lie-related distracters when telling the truth we report. Therefore, we could demonstrate that in scenarios in which it is beneficial to lie, a lie is activated phonologically when telling the truth. This explains why lie-related distracters could slow truth telling in our experiment.

Debey and colleagues took the position that the truth production simply encompasses a single step (2014), which makes truth production different from lying in the sense that lie production is likely to involve several steps, e.g. constructing a lie (Walczyk et al., 2003). Based on Debey et al.'s proposal that truth production is a one-step process in which simply the truth is produced, we ruled out that a lie could be generated parallel to the truth. Therefore, we hypothesized to find no indirect distracter effects when telling the truth initially. In the current study we could show an unexpected effect of co-activated lies on truth telling. Yet, the current results are not contradictory to Debey et al.'s idea that truth telling encompasses one single step, because in our current experiment the lies were predefined in the card game. Due to the lies being predefined, there was no extra step of lie construction necessary. Therefore truth telling can still have only involved the single step of delivering the truthful message, but a lie was still co-active. Hence, it might be helpful to run an experiment which investigates whether the lie can only be co-active during truth telling in contexts in which a lie would already be predefined or if this does not play any role.

Limitations and future directions

First of all, contrary to our predictions, the card type did not have a significant effect on object naming in the GLMM analysis. The absence of a significant main effect is however due to the structure of the data in the analysis. As all trials in which participants told a lie when they saw a trump card were excluded from the analysis, trump cards could only lead to truth telling. Hence there was no variation possible in this condition. Therefore, we decided to run an additional analysis, including the previously excluded 100 trials in which participants lied when seeing a trump card. In this analysis, the effect of card type on naming is significant (b = -4.38, SE = 0.30, p < .001). Thus, we can also confirm our hypothesis that participants would preferably lie when they see losing cards. As telling the truth about when seeing a trump guaranteed five points each time, it is actually surprising that participants lied at all when they saw a trump card. In the debriefing, when asked about response strategies, four participants declared they tried to deceive in these trials to confuse their counterpart by responding irrationally from time to time. Other participants mentioned strategies such as always lying on the first card shown in each block. Therefore, the unexpected amount of deception attempts when trump cards were shown is most likely due to certain strategies participants applied to avoid detection by their opponent.

One of the main differences between producing truthful statements and lying is that the truth does not have to be constructed (e.g. Debey et al., 2014). There is only one truth, but there are many possible lies to choose from. Therefore, a direct comparison of truth telling and deception naming times confounds the different steps of lie production and hereby makes it impossible to attribute any findings to a sole experimental manipulation. In our experiment this confound is present as well. In the truth condition participants just had to process the object they saw and name it. When lying, on the other hand, participants had to identify the object and retrieve its associate which they would consequently say out loud. To work around this issue, we based our paradigm on the use of an unrelated baseline condition: the used distracter words are reassigned unrelatedly, which can be seen as a baseline condition. Unrelated distracter words are supposed to not affect speech production in any way (e.g. Schriefers , Meyer & Levelt, 1990), and as each distracter condition had its own unrelated condition baseline, differences between truth telling and lying, such as effects of memory retrieval, are constant for related and unrelated distracters and can be ruled out as a confound. This way, ideally only the influence of related distracter words on speech production explains differences in reaction times. In the light of the importance of the unrelated conditions, the fact that the naming times of stimuli with unrelated direct distracters differ from the condition with unrelated indirect distracters limits the interpretability of our data. When participants lied, the unrelated truth-related distracters are linked to the slowest naming times out of all the distracter conditions. Hence, it is possible that the unrelated distracters influenced naming times and in fact lead to slower RTs. This could have covered up effects of interference or have increased facilitative effects. In line with this, it is possible that this contributed to the big effect size we observed, especially of the phonological facilitation effect when lying (d = -0.22), compared to the facilitation effect when telling the truth (d = -0.10). A reason behind the slow unrelated condition might be that the two distracters on one card interacted with the supposedly unrelated object. This could have affected naming times in an unexpected manner. To clarify the role of the unrelated distracters in the current data, we recommend attempting a replication of the study using a stimulus list with different distracter words to rule out stimulus effects as a confound in the current results.

A second notable limitation to the current study is that the individual sessions were quite brief, lasting only one to one and a half hours per participant. Hence, when participants told considerably more deceptive utterances than truthful ones or vice versa, a sufficient amount of trials for analysis could not be collected. Overall, 17 participants had to be excluded from the analysis because they did not lie enough or lied too much. Further, for nine participants, less than 30 trials in the lying condition with indirect distracters could be obtained. A major contributing factor to the study’s proneness to response strategies, might be the briefness of the experiment, as each participant only executed 384 trials. Conducting such a short experiment creates the problem of trial exclusion due to naming errors or other reasons having a much bigger impact. Therefore, it might be possible that existing effects do not show in the data because of a lack of power. For this reason, we propose future studies with the design of the current study, but with more trials for each distracter condition. Extending the experiment to obtain more trials per condition for each participant could help to clarify the nature of the observed results in the current experiment. As the hypothesized interference of truth-related distracters when lying was descriptively observable in means ($M_{\text{unrelated}}$ = 1056.53 ms, $M_{\text{indirecty related}}$ = 1073.28 ms) but not statistically significant, we hypothesize that it can only be detected as the experimental power is increased. Alternatively, a replication of the current pattern of results would be extremely insightful as it would favour the idea that the truth is inhibited before phonological encoding.

Another limitation of the proposed design in this study is that we only balanced out the distracter conditions across truth telling and lying in general. This has the disadvantage of confounding the influence of card types and object naming. Whilst lying is automatically equivalent to seeing a losing card and naming a trump card, truth telling can be either seeing a trump card and naming it or seeing a losing card and naming it. Yet, we failed to incorporate a possible card type effect and only displayed direct distracters with trump cards and only indirect distracters when losing cards with no reward were displayed. Thus, the design lacked direct distracters displayed when losing cards were displayed with no reward. Hence, for a follow-up experiment we would recommend increasing the number of losing cards being presented without a reward, to facilitate the comparison of the effects of direct and indirect distracters as participants tell the truth about seeing losing cards. Hereby, one would be able to compare the effects of truth telling and lying when naming of only one type of card. Trump cards should still be included to keep up the card game cover story, but instead they might be used as filler items. Furthermore, increasing the proportion of trials in which participants supposedly tell the truth about seeing a losing card could decrease participants' constant pre-activation of the trump objects name, as the latter would be named less often than in the current study. Therefore we could rule out the different types of cards as a possible confound in the experimental setup. Further, by replicating this study with more trials, we hope to increase the chances to detect the hypothesized co-activation of truth and lie when lying.

It is in the nature of lying that the given responses serve to deceive. Previous studies have observed that RT differences between truth telling and lying can be covered up by strategies to avoid detection (e.g. Ben-Shakhar , 2011). We are no exception in not being able to rule out that the social context in the current experiment falsified naming times. Despite the instruction to name as quickly and accurately as possible, it is possible that participants deliberately slowed their naming times when telling the truth. Herewith the RT difference between lying and telling the truth could be covered up in single trials. In this case, we might have measured the participants' abilities to delay an already produced truth. Hence, the mediated semantic interference effect we observed when participants told the truth could have reflected a response strategy. As participants saw lie-related distracter words, they might have been reminded to avoid detection and slowed their responses. The deliberate delay of truthful responses would also explain why participants were slower than lying in this condition (cf. Table 3). However, avoiding detection is part of lying (Ben-Shakhar, 2011) and can therefore not be avoided completely in ecologically valid settings. Furthermore, lying was overall slower than telling the truth in the current study. Thus, it is unlikely that response strategies explain the mediated semantic interference effect we observed.

In spite of our designs' efficiency, it is generally difficult to manipulate different stages of speech production, e.g., conceptual, lexical, and phonological planning, independently of each other (Rose, Spalek, & Abdel Rahman, 2015). Thus, RTs could reflect multiple components associated with deception. In line with this, different effects in opposing directions might have balanced each other out in the present set of results. Therefore, it is possible that the inhibitory effect of truth-related distracters on lying is existent but hidden in our data. In line with the findings of Debey at al. (2014), there is a possibility that the distracter words we used had a facilitating effect during conceptual encoding, whilst they caused interference during phonological encoding, as we predicted. The facilitated conceptual preparation of a lie in turn might have evened out the interference caused by the co-activated truth. In line with this idea, some participants in our study reported that the display of a distracter that was in any way related to the utterance helped the production process since it facilitated memory retrieval of the object pair and hereby of the desired lie. Thus, the absence of prolonged naming times of lying in the presence of truth related distracter words does not necessarily mean that the truth is not co-activated during lying. To clarify the role of the truth during deceptive speech production, future studies should therefore attempt to separate speech production from decision and construction processes. As a possible way to test distracter effects on early processes such as conceptual preparation, it could be interesting to vary the stimulus-onset asynchrony (SOA) between picture and distracter. The idea is the following: if truth-related distracters slow down lie responses when displayed at positive SOAs (i.e. distracters displayed after object onset), participants are already at the phonological stage of the naming response preparation, the interference is likely to be localized at the word form level (Glaser & Düngelhoff, 1984). Hence, when using a positive

SOA, the chances to detect the hypothesized co-activation of truth and lie during phonological encoding could be increased.

Conclusion

To summarize, we successfully tested a novel design to investigate the speech production of lying. We found a mediated semantic interference effect of lie-related distracters as participants told the truth, which suggests that in contexts, which encourage lying, a lie might be co-activated phonologically when telling the truth. On the other hand, we found no effect of truth-related distracters as participants lied. In conclusion, we found no evidence supporting our hypothesis that the truth and the lie are co-active during speech production, but we could show an unexpected effect of co-activated lies on truth telling. This surprising finding suggests that truth telling might be more complex than assumed so far in the literature. Furthermore, the design we brought forward is apt to detect effects on speech production and therefore it is suitable to further investigate the role of the truth during speech production.

The presented study was a first attempt to describe the production of deceptive messages on the level of speech production. Yet, the current results also reveal some constraints, such as the briefness of the experiment. Thus, further research is needed to better understand how such complex utterances as lies are produced.

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Tables

Table 1

Expected response types and number of trials per distracter condition: Participants are incentivized say the truth in half of all trials and to lie in the other half

Card type; Reward											
Trump card; 5 Points				Losingcard; 0 Points				Losing card; 5 Points			
Expected Naming											
Truth		Lie		Truth		Lie		Truth		Lie	
2304		0		2304		0		0		4608	
N / Distracter condition											
Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect
2304	0	0	0	0	2304	0	0	0	0	2304	2304

Note: N per distracter conditions including the unrelated condition to each type of distracter

Table 9

Observed answers and resulting number of trials per distracter condition

Card type; Reward											
Trump card; 5 Points				Losing card; 0 Points				Losing card; 5 Points			
Naming											
Truth		Lie		Truth		Lie		Truth		Lie	
2090		0		1419		734		1240		3000	
N / Distracter condition											
Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect
2092	0	0	0	0	1419	734	0	622	618	1506	1494

Note: N per distracter conditions including the unrelated condition to each type of distracter

Figures

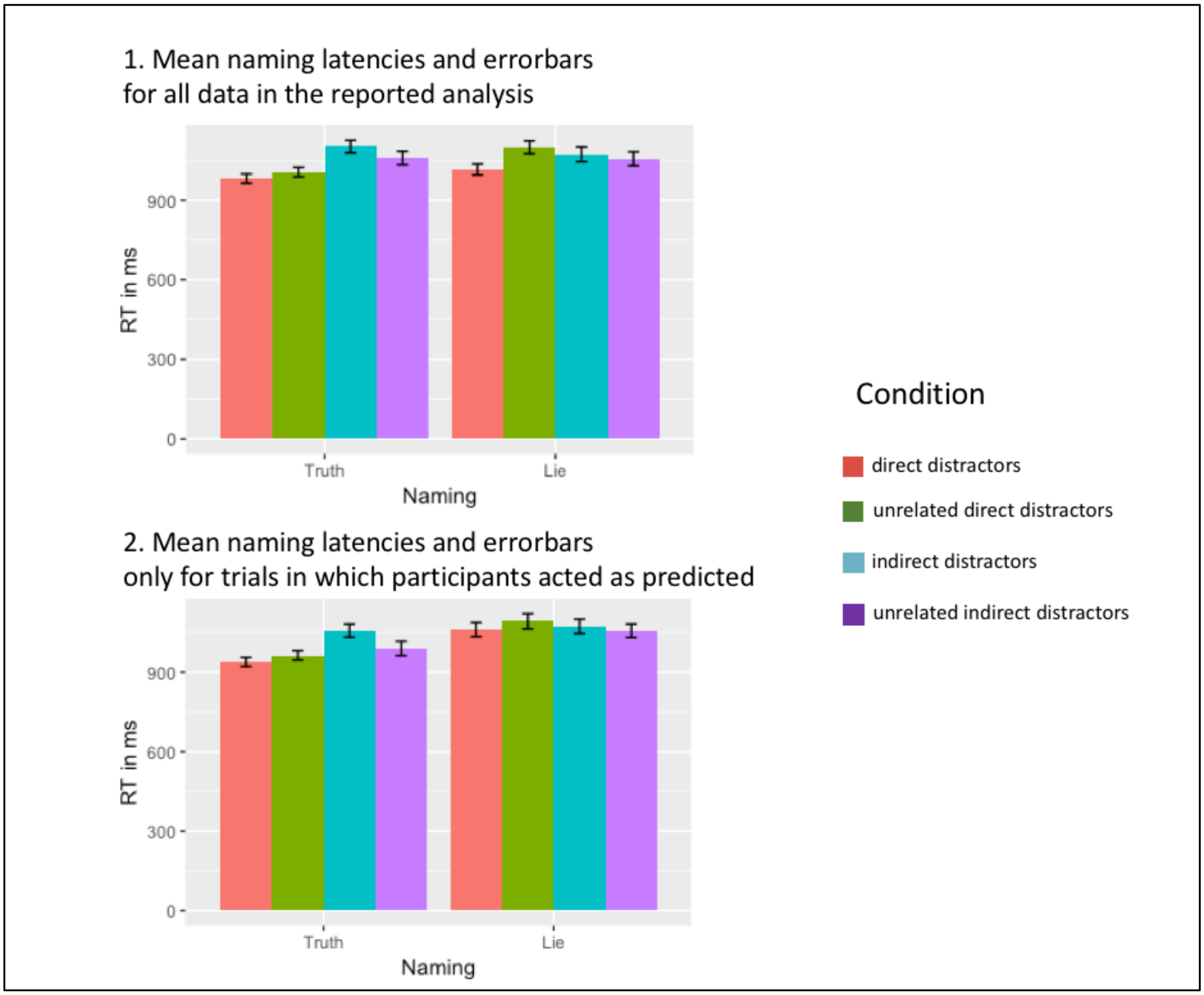

Figure 4. Comparison of data including unpredicted answers and data excluding unpredicted answers. The top graph shows reaction times in means for the data we report in the analysis. The bottom graph shows mean reaction times of those data excluding the cases in which participants lied despite not being rewarded or said the truth despite seeing a losing card and being rewarded.

Appendix

Objects and words used in the experiment

Object names and translations		Phonologically directly related word pairs	Unrelated direct words	Phonologically indirectly related word pairs	Unrelated indirect words
Object pairs	Objects	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*
		Category pair 1:	**Meerestiere vs. Werkzeug** ***Sea animals vs. tools***		
Muschel vs. Schraube *clam vs. screw*	**Muschel** ***clam***	Musik Büschel	Adverb Vulkan	Scharlatan Laube	Furcht Dasein
	Schraube ***screw***	Schraffur Haube	Klan Daten	Muskat Getuschel	Wachs Garten
Lachs vs. Zange *salmon vs. pliers*	**Lachs** ***salmon***	Lama Klacks	Kader Flipper	Zahnarzt Folge	Bank Giebel
	Zange ***pliers***	Zahlung Wange	Ohnmacht Boykott	Laken Dachs	Kammer Widerstand
Schildkröte vs. Pflug *turtle vs. plow*	**Schildkröte** ***turtle***	Schicht Morgenröte	Himmel Leibchen	Pflicht Krug	Titan Holz
	Pflug ***plow***	Pflaster Zug	Labrador Fußball	Schirm Hüfte	Termin Würfel
Seeigel vs. Harke *sea urchin vs. rake*	**Seeigel** ***sea urchin***	Segen Riegel	Trog Barbier	Handlung Kloake	Feinheit Zucker
	Harke ***rake***	Habicht Barke	Zigarre Krieger	Selbst Pegel	Bankrott Metzger
Krabbe vs. Bohrer *crab vs. drill*	**Krabbe** ***crab***	Kragen Gabe	Papst Training	Bogen Spieler	Strich Schritt
	Bohrer ***drill***	Boden Fahrer	Geisel Streich	Krach Narbe	Immigrant Tyrannei

Object names and translations		Phonologically directly related word pairs	Unrelated direct words	Phonologically indirectly related word pairs	Unrelated indirect words
Object pairs	Objects	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*
Qualle vs. Spachtel *jellyfish vs scraper*	**Qualle** ***jellyfish***	Quantum Hülle	Blei Recht	Spanngurt Kegel	Regung Verkäufer
	Spachtel ***scraper***	Sport Wachtel	Zaster Tradition	Quader Zwille	Madonna Gestein
Seestern vs. Feile *starfish vs. rasp*	**Seestern** ***starfish***	Senf Zaudern	Geisir Ziffer	Feinheit Meile	Oval Kamera
	Feile ***rasp***	Feigling Variable	Handstand Technik	Sektor Ziffern	Bibel Parabel
Pinguin vs. Wasserwaage *penguin vs. mechanic's level*	**Pinguin** ***penguin***	Pinsel Bein	Schwur Speicher	Watt Schräglage	Lager Tragik
	Wasserwaage ***mechanic's level***	Wahl Auslage	Fabel Getränk	Pingpong Ruin	Kompass Schneider
		Category pair 2:	**Insekten vs. Kleidungsstücke** ***insects vs. garments***		
Fliege vs. Gürtel *fly vs. belt*	**Fliege** ***fly***	Flieder Ziege	Musik Klacks	Gültigkeit Viertel	Scharlatan Krug
	Gürtel ***belt***	Güterzug Mörtel	Schicht Habicht	Flimmern Anklage	Krach Haken
Biene vs. Frack *bee vs. tails*	**Biene** ***bee***	Bilanz Miene	Zahlung Riegel	Fraktur Pack	Muskat Schirm
	Frack ***tails***	Fracht Wrack	Schraffur Wachtel	Bildnis Hüne	Sektor Pingpong

Object names and translations		Phonologically directly related word pairs	Unrelated direct words	Phonologically indirectly related word pairs	Unrelated indirect words
Object pairs	Objects	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*
Schmetterling vs. Pullover *butterfly vs. pullover*	**Schmetterling** ***butterfly***	Schmerz Ausgang	Wange Morgenröte	Purist Metapher	Karre Röte
	Pullover ***pullover***	Putz Kescher	Haube Barke	Schmuck Ring	Hüfte Kloake
Mücke vs. Schal *mosquito vs. scarf*	**Mücke** ***mosquito***	Mützchen Brücke	Boden Gitter	Schatten Pedal	Zahnarzt Handlung
	Schal ***scarf***	Schach Qual	Quantum Glibber	Müsli Lücke	Ziffern Balkan
Hummel vs. Kappe *bumblebee vs. cap*	**Hummel** ***bumblebee***	Hunger Schädel	Pflaster Sport	Kalk Sippe	Ruin Selbst
	Kappe ***cap***	Kapern Welpe	Segen Bein	Hummer Primel	Spanngurt Floß
Ameise vs. Pantoffel *ant vs. slipper*	**Ameise** ***ant***	Amboss Reise	Kragen Zaudern	Paarung Knorpel	Dachs Bogen
	Pantoffel ***slipper***	Partitur Trampel	Darlehen Rabatt	Amerika Erbse	Watt Geiz
Skorpion vs. Brosche	**Skorpion** ***scorpion***	Skalpell Region	Lama Zug	Brief Asche	Getuschel Pegel
	Brosche ***brooch***	Brand Depesche	Pinsel Feigling	Skonto Union	Kegel Kartoffel
Libelle vs. Kaftan *dragonfly vs. caftan*	**Libelle** ***dragonfly***	Licht Schule	Jünger Senf	Kanu Organ	Pflicht Spieler
	Kaftan ***caftan***	Kachel Median	Fahrer Maffia	Liebling Tabelle	Quader Schwester

Object names and translations		Phonologically directly related word pairs	Unrelated direct words	Phonologically indirectly related word pairs	Unrelated indirect words
Object pairs	Objects	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*
		Category pair 3:	**Gemüse vs. Fortbewegungsmittel** ***vegetables vs. means of transportation***		
Salat vs. Lastwagen *lettuce vs. lorry*	**Salat** ***lettuce***	Salbe Nougat	Apfelsine Farbe	Lava Rasen	Anklage Kante
	Lastwagen ***lorry***	Lasche Wogen	Küche Jacke	Sage Kalifat	Periode Ritze
Zwiebel vs. Schlitten *sleigh vs. onion*	**Zwiebel** ***onion***	Zwang Trubel	Auslage Gehilfe	Schlucht Tuten	Tee Elend
	Schlitten ***sleigh***	Schlamm Alpen	Reise Walze	Zwiespalt Handel	Meile Tabelle
Paprika vs. Fahrrad *paprika vs. bike*	**Paprika** ***paprika***	Papier Afrika	Hülle Schule	Faden Blutbad	Vaseline Narbe
	Fahrrad ***bike***	Farbe Kamerad	Lasche Tiefe	Pappe Alaska	Schräglage Einlage
Gurke vs. Motorrad *cucumber vs. motorcycle*	**Gurke** ***cucumber***	Gurren Jacke	Spender Büschel	Motivation Pfad	Kordel Feier
	Motorrad ***motorcycle***	Mobilität Grad	Vitamin Fabrikant	Gurgel Birke	Raster Fakir
Kürbis vs. Bagger *pumpkin vs. excavator*	**Kürbis** ***pumpkin***	Kürzel Erlaubnis	Variable Hort	Bandit Nager	Adresse Dämpfe
	Bagger ***excavator***	Ball Führer	Exot Erbschaft	Kürzung Zeugnis	Grotte Diskette

Object names and translations		Phonologically directly related word pairs	Unrelated direct words	Phonologically indirectly related word pairs	Unrelated indirect words
Object pairs	Objects	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*
Tomate vs. Gondel *tomato vs.* *cable car*	**Tomate** ***tomato***	Tollwut Hütte	Kampf Koma	Gorilla Windel	Reaktion Ständer
	Gondel ***cable car***	Gold Hantel	Kescher Verfahren	Tombola Küste	Gier Nicken
Fenchel vs. Traktor *fennel vs.* *tractor*	**Fenchel** ***fennel***	Feind Gejodel	Salbe Rebe	Transport Prozessor	Sippe Ratsche
	Traktor **tractor**	Tradition Labrador	Kapelle Sense	Feld Kordel	Erdbeben Sage
Radieschen vs. Segelboot *radish vs.* *sailboat*	**Radieschen** ***radish***	Rabatt Leibchen	Wahl Eleganz	Sechstel Patriot	Asche Laube
	Segelboot ***sailboat***	Sense Exot	Depesche Limonade	Raspel Drachen	Zwille Folge
		Category pair 4:	**Obst vs. Waffen** ***fruits vs. weapons***		
Apfel vs. Peitsche *apple vs. whip*	**Apfel** ***apple***	Appetit Tafel	Flieder Bilanz	Pessimist Ratsche	Gültigkeit Kalk
	Peitsche ***whip***	Peiniger Klatsche	Schmerz Mützchen	Apparat Rüffel	Metapher Skonto
Trauben vs. Kanone *grapes vs.* *canon*	**Trauben** ***grapes***	Tracht Glauben	Güterzug Schach	Kanzel Zone	Viertel Hummer
	Kanone ***canon***	Kanzlei Ebene	Partitur Gejodel	Trauer Laden	Purist Liebling

Object names and translations		Phonologically directly related word pairs	Unrelated direct words	Phonologically indirectly related word pairs	Unrelated indirect words
Object pairs	Objects	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*
Zitrone vs. Degen *lemon vs. epee*	**Zitrone** ***lemon***	Zitat Bühne	Mörtel Ausgang	Deckel Wagen	Schmuck Primel
	Degen ***epee***	Debakel Regen	Amboss Brand	Ziel Krone	Kanu Gorilla
Birne vs. Dolch *pear vs. dagger*	**Birne** ***pear***	Bier Kaserne	Qual Region	Dom Elch	Flimmern Paarung
	Dolch **dagger**	Dolmetscher Kelch	Zuwachs Schädel	Billard Laterne	Ring Organ
Ananas vs. Lanze *pineapple vs. lance*	**Ananas** ***pineapple***	Anstalt Plexiglas	Hunger Kamm	Land Zitze	Fraktur Bereich
	Lanze ***lanze***	Latein Sülze	Widerspruch Median	Anspruch Gas	Schatten Motivation
Pfirsich vs. Armbrust *peach vs. crowssbow*	**Pfirsich** ***peach***	Pforte Vergleich	Brücke Ziege	Armatur Frust	Knorpel Lücke
	Armbrust ***crossbow***	Arena Kontrast	Miene Welpe	Pfarrer Bereich	Erbse Laken
Banane vs. Schlagring *banana vs. knuckle-duster*	**Banane** ***banana***	Balken Drohne	Wrack Kapern	Schlacht Abhang	Pack Amerika
	Schlagring ***knuckle-duster***	Schloss Empfang	Putz Kachel	Banjo Karawane	Pedal Tropen
Erdbeere vs. Dreizack *strawberry vs. trident*	**Erdbeere** ***strawberry***	Erbschaft Säure	Fracht Skalpell	Dreidel Lack	Bildnis Brief
	Dreizack ***trident***	Drama Sack	Trampel Licht	Erdbeben Niere	Müsli Union

Object names and translations		Phonologically directly related word pairs	Unrelated direct words	Phonologically indirectly related word pairs	Unrelated indirect words
Object pairs	Objects	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*
		Category pair 5:	**Säugetiere vs. Möbel** ***mammals vs. furniture***		
Fuchs vs. Teppich *fox vs. rug*	**Fuchs** ***fox***	Fußball Zuwachs	Eltern Erlaubnis	Tee Strich	Pappe Küste
	Teppich ***rug***	Technik Streich	Regen Klage	Furcht Wachs	Lava Elan
Tiger vs. Schrank *tiger vs. cabinet*	**Tiger** ***tiger***	Tiefe Krieger	Hütte Aal	Schritt Bank	Hüne Pfad
	Schrank ***cabinet***	Schrei Getränk	Grad Hantel	Titan Lager	Bandit Drachen
Kaninchen vs. Regal *rabbit vs. shelf*	**Kaninchen** ***rabbit***	Kapelle Verfahren	Feind Gabe	Regung Oval	Schlucht Zwiespalt
	Regal ***shelf***	Rebe Aal	Mobilität Dichte	Kante Linsen	Feld Banjo
Elefant vs. Kamin *elefant vs. fireplace*	**Elefant** ***elefant***	Eleganz Fabrikant	Schwefel Bildung	Kammer Termin	Handel Windel
	Kamin ***fireplace***	Kamm Vitamin	Hagel Schrei	Elend Immigrant	Sechstel Prozessor
Dackel vs. Kommode *dachshund vs. dresser*	**Dackel** ***dachshund***	Darlehen Hagel	Nougat Führer	Kompass Periode	Rasen Faden
	Kommode ***dresser***	Koma Limonade	Alpen Gold	Dasein Giebel	Nager Patriot

Object names and translations		Phonologically directly related word pairs	Unrelated direct words	Phonologically indirectly related word pairs	Unrelated indirect words
Object pairs	Objects	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*
Kamel vs. Hocker *camel vs. stool*	**Kamel** ***camel***	Kampf Schwefel	Tollwut Wogen	Holz Zucker	Birke Blutbad
	Hocker ***stool***	Hort Glibber	Rate Serviette	Kamera Würfel	Tombola Geschlecht
Biber vs. Matratze *beaver vs. mattress*	**Biber** ***beaver***	Bildung Spender	Zwang Afrika	Madonna Ritze	Kalifat Gurgel
	Matratze ***mattress***	Maffia Walze	Gurren Kürzel	Bibel Verkäufer	Kürzung Transport
Widder vs. Gardine *ram vs. curtain*	**Widder** ***ram***	Widerspruch Jünger	Trubel Papier	Garten Vaseline	Tuten Alaska
	Gardine ***curtain***	Garn Apfelsine	Ball Schlamm	Widerstand Metzger	Zeugnis Raspel
		Category pair 6:	**Vögel vs. Musikinstrumente** ***birds vs. musical instruments***		
Adler vs. Trommel *eagle vs. drum*	**Adler** ***eagle***	Adverb Kader	Klatsche Bühne	Tragik Kartoffel	Karawane Niere
	Trommel ***drum***	Trog Himmel	Kaserne Säure	Adresse Schneider	Krone Zitze
Papagei vs. Geige *parrot vs. violin*	**Papagei** ***parrot***	Papst Blei	Appetit Bier	Gestein Einlage	Wagen Billard
	Geige ***violin***	Geisir Klage	Zitat Kelch	Parabel Tyrannei	Armatur Linsen
Schwan vs. Flöte *swan vs. flute*	**Schwan** ***swan***	Schwur Vulkan	Kanzlei Anstalt	Floß Röte	Pessimist Pfarrer
	Flöte ***flute***	Flipper Rate	Empfang Vergleich	Schwester Balkan	Ziel Abhang

Object names and translations		Phonologically directly related word pairs	Unrelated direct words	Phonologically indirectly related word pairs	Unrelated indirect words
Object pairs	Objects	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*	*Initial overlap* *Final overlap*
Geier vs. Trompete *vulture vs. trumpet*	**Geier** ***vulture***	Geisel Barbier	Kamerad Arena	Tropen Diskette	Kanzel Lack
	Trompete ***trumpet***	Training Dichte	Plexiglas Schloss	Geiz Feier	Land Kübel
Reiher vs. Klarinette *egret vs. clarinet*	**Reiher** ***egret***	Recht Ziffer	Tracht Balken	Klient Grotte	Apparat Gas
	Klarinette ***clarinet***	Klan Serviette	Latein Garn	Reaktion Ständer	Dom Schlacht
Specht vs. Gitarre *woodpecker vs. guitar*	**Specht** ***woodpecker***	Speicher Ohnmacht	Peiniger Dolmetscher	Gier Karre	Laden Dreidel
	Gitarre ***guitar***	Gitter Zigarre	Debakel Drama	Speck - Geschlecht	Anspruch Rüffel
Elster vs. Harfe *magpie vs. harp*	**Elster** ***magpie***	Elstern Zaster	Tafel Sack	Haken Dämpfe	Deckel Frust
	Harfe ***harp***	Handstand Gehilfe	Glauben Kontrast	Elan Raster	Speck Klient
Küken vs. Fagott *fledgling vs. bassoon*	**Küken** ***fledgling***	Küche Daten	Drohne Ebene	Fakir Bankrott	Zone Laterne
	Fagott ***bassoon***	Fabel Boykott	Sülze Pforte	Kübel Nicken	Trauer Elch