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ORIGINAL ARTICLE

Lie, truth, lie: the role of task switching in a deception context

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Abstract A cornerstone of the task switching literature is the finding that task performance is typically slower and more error-prone when the task switches than when it repeats. So far, deception research has largely ignored that such cognitive switch costs should also emerge when switching between truth telling and lying, and may affect the cognitive cost of lying as reflected in higher prefrontal brain activity and slower and less accurate responding compared to truth telling. To get a grasp on the relative size of the switch costs associated with lying and truth telling, the current study had participants perform a reaction time-based deception task, in which they alternated between lying and telling the truth to yes/no questions that were related to activities performed in the lab (Experiment 1) or neutral autobiographical facts (Experiment 2). In both experiments, the error and reaction time switch costs were found to be equally large for switching from truth telling to lying and from lying to truth telling. This symmetry in switch costs can be explained from the hypothesis that lying requires a first step of truth telling, and demonstrates that task switching does not contribute to the cognitive cost of lying when the repetition/switch ratio is balanced. Theoretical and methodological implications are considered.

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Introduction

Recent deception literature is characterized by a vast amount of studies that investigated the validity and practical use of the cognitive view of lying (Abe, 2011; Vrij & Granhag, 2012; Walczyk, Igou, Dixon, & Tcholakian, 2013). This view states that lying is cognitively more demanding than truth telling (Vrij & Granhag, 2012). Several lines of research have found support for the view that lying comes with a cognitive cost. The cognitive load associated with lying is for example reflected in longer reaction times (RTs) and a higher error rate compared to truth telling (e.g., Verschuere, Spruyt, Meijer, & Otgaar, 2011; Williams, Bott, Patrick, & Lewis, 2013; but see Suchotzki, Verschuere, Crombez, & De Houwer, 2013). Furthermore, brain imaging studies have consistently found a higher activity of the prefrontal cortex during lying when contrasted to truth telling (Abe, 2011). From the notion that the prefrontal cortex is crucially linked to executive control (Stuss & Knight, 2013), researchers have inferred the hypothesis that compared to truth telling lying may depend more heavily on response inhibition, working memory updating, and shifting (Abe, 2011; Christ, Van Essen, Watson, Brubaker, & McDermott, 2009; Gombos, 2006), that is, the main executive functions as defined by Miyake and colleagues (Miyake et al., 2000). Response inhibition may be required to suppress the dominant truth response, working memory updating may help to keep the truth active while formulating the lie, and shifting may be needed to flexibly switch between the mental sets associated with truthful and deceptive responses (Christ et al., 2009). So far, evidence has been found for the idea that the truth is initially activated during deception and needs to be inhibited (e.g., Debey, De Houwer, & Verschuere, 2014a; Duran, Dale, & McNamara, 2010; Hadar, Makris, & Yarrow, 2012; Vartanian et al., 2013). Some studies also addressed the importance of working memory updating in deception (e.g., Ambach, Stark, & Vaitl, 2011; Evans & Lee, 2011; Morgan, LeSage, & Kosslyn, 2009; Visu-Petra, Varga, Miclea, & Visu-Petra, 2013). However, mixed results have been obtained with regard to the contribution of shifting to the cognitive cost of lying. The current study therefore sought to further clarify its role.

The few studies that have examined shifting in a deception context have highlighted the role of shifting *within* lying, which we will refer to as *mental set shifting*. Mental set shifting in lying can be defined as the disengagement of the irrelevant truth telling task set and subsequent engagement of the relevant lying task set. In a meta-analysis, Christ and colleagues (2009) contrasted the brain regions that are consistently more active during lying than truth telling with the brain regions that are crucially linked to response inhibition, working memory updating, and shifting. Whereas deception regions overlapped considerably with regions associated with response inhibition and working memory updating, only little overlap was found with shifting regions. Visu-Petra and colleagues examined the role of shifting in the RT-based Concealed Information Test (RT-CIT; Verschuere, Ben-Shakhar, & Meijer, 2011), a deception paradigm in which participants deceitfully deny recognition of known items (probes) and truthfully deny recognition of unknown items (irrelevants). They found that the performance on a shifting task positively correlated ($r = .57$) with the accuracy to deceive (Visu-Petra, Miclea, & Visu-Petra, 2012). However, truth telling accuracy correlated to a similar degree with shifting ($r = .68$). In a later study, the authors more convincingly proved the larger role of shifting in lying by showing that executing the RT-CIT with a concurrent shifting task impoverished deceiving more than truth telling (Visu-Petra et al., 2013).

The correlation between shifting and truth telling performance in the study of Visu-Petra et al. (2012) may point to another type of shifting being at play in deception paradigms that would also affect truth telling and that potentially influenced the negative findings of Christ et al. (2009). Because typical deception paradigms require participants to alternate between truth telling and lying, *task switching* would occur when switching from truth telling toward lying, or vice versa. A robust finding in task switching literature is the observation of a switch cost, showing that participants are slower and more error-prone when the task switches than when the task repeats (see Kiesel et al., 2010; Monsell, 2003; Vandierendonck, Liefooghe, & Verbruggen, 2010, for reviews). Moreover, when tasks differ in strength, the switch cost has repeatedly found to be asymmetric in the sense that switching to the stronger task comes with a larger switch cost than switching to the weaker task (e.g., Allport, Styles, & Hsieh, 1994). Because deception researchers usually do not balance truth telling and lying over repetition and switch trials, either by presenting lie and truth trials in a complete random order or using blocked designs (cf. fMRI studies), switch costs may obscure the role of mental set shifting in lying, and—more generally—affect the measurement of the behavioral and neurological cognitive cost of lying. Even in balanced designs, switching may differentially impact upon truth telling and lying, and thus shape the cognitive cost of lying. It is therefore important to investigate the relative size of the switch cost associated with truth telling and lying.

To our knowledge, only two studies have alluded to the impact of task switching on truth telling and lying. In a study of Osman and colleagues, participants completed two blocks of an RT-based computer task, in which they answered the same questions truthfully or deceptively depending on the condition they were assigned to: Truth (block 1)–truth (block 2), lie–lie, truth–lie, or lie–truth (Osman, Channon, & Fitzpatrick, 2009). Lying appeared to be slower than truth telling, yet participants in the truth–lie condition were not slower than in the lie–lie condition. However, a potential switch cost may have been obscured by the between-subjects comparison, and particularly by the blocked design. Another shortcoming of the study is that the effect of switching from lying to truth telling was not analyzed. In her unpublished doctoral dissertation, Williams (2012; Chapter 3) examined the RT switch cost for both truth telling and lying. However, the five experiments she describes were not always optimally designed and delivered inconsistent results. First, four experiments were reanalyzed in which the ratio of repetition and switch trials was not balanced. In a fifth study in which the repetition/switch ratio was balanced, the switch costs for truth telling and lying were found to be equally large. Yet striking was that a post hoc test revealed no significant switch cost for lying. The fact that participants could prepare for the task and choose between multiple deceptive responses may have induced unwanted noise (Verhoef, Roelofs, & Chwilla, 2009; Williams, 2012). In sum, so far no study has provided an adequate test of the relative impact of task switching on truth telling and lying. The current study is a first attempt to fill this gap in the literature.

Our study contrasted two hypotheses on the relative size of the truth telling and lying switch cost. As mentioned earlier, several studies have shown that switching between tasks of unequal strength due to a difference in task dominance (Allport et al., 1994), difficulty (Schneider & Anderson, 2010), familiarity (Yeung & Monsell, 2003a), or practice (Yeung & Monsell, 2003b) results in a relatively larger switch cost for the strong task. In their seminal paper, Allport et al. (1994) found that despite participants being slower to name the ink color than to read the color word of incongruent color words (e.g., RED in blue) in a Stroop task (Stroop, 1935), word reading was associated with larger switch costs than color naming (see also Allport & Wylie, 2000; Yeung & Monsell, 2003a, 2003b). Similar asymmetric switch costs have been observed in a variety of other contexts, such as when switching between languages of different dominance (e.g., Campbell, 2005; Meuter & Allport, 1999; Philipp, Gade, & Koch, 2007), pro-saccades and anti-saccades (e.g., Cherkasova, Manoach, Intriligator, & Barton, 2002; Manoach et al., 2007; Vermeiren, Liefooghe, & Vandierendonck, 2010), levels of arithmetic difficulty (e.g., Ellefson, Chapiro, & Chater, 2006; Koch, Prinz, & Allport, 2005; Lemaire & Lecacheur, 2010; Schneider & Anderson, 2010), and digit categorizations (Arbuthnott, 2008). This seemingly counterintuitive phenomenon has traditionally been explained on the basis of the interference account on switching. This view considers switch costs to reflect a carryover effect of a previously activated task set due to a persistent activation of the preceding task set (i.e., the set of task parameters that program the system to perform processes such as stimulus identification, response selection and response execution; Logan & Gordon, 2001). This passive dissipation of the previous task set facilitates performance when the task repeats, but when the task switches, the task set causes interference and needs to be inhibited (Allport et al., 1994; see Koch, Gade, Schuch, & Philip, 2010, for a review). When switching between tasks of unequal strength, executing the weak task would require strong inhibition of the strong task. When the strong task set becomes relevant again, it would therefore take a lot of time and effort to overcome this suppression, leading to a large switch cost. In contrast, only little inhibition of the weak task would be needed when switching to the strong task, making for a relatively small switch cost for the weak task (Allport & Wylie, 2000). Because the truth is the easier, dominant, more rehearsed and more familiar response (Duran et al., 2010; Hadar et al., 2012), truth telling can be considered as a stronger "task" than lying. Consequently, one plausible hypothesis is that an asymmetric switch cost will arise when switching between truth telling and lying, where it would be more difficult to switch from lying to truth telling than vice versa.

It is, however, important to acknowledge that several studies have failed to find asymmetric switch costs (Costa & Santesteban, 2004; Hernandez & Kohnert, 1999; Hübner, Kluwe, Luna-Rodriguez, & Peters, 2004; Monsell, Yeung, & Azuma, 2000; Reuter, Philipp, Koch, & Kathmann, 2006; Tarłowski, Wodniecka, & Marzecová, 2013). Moreover, some authors observed reversed switch cost asymmetries (Arbuthnott, 2008; Yeung & Monsell, 2003a) or asymmetries in the absence of switching (Bryck & Mayr, 2008; Schneider & Anderson, 2010). This suggests that asymmetric switch costs may be the result of a complex interplay between several endogenous and exogenous factors (Arbuthnott, 2008; Gilbert & Shallice, 2002; Yeung & Monsell, 2003a). A recent finding of our lab points to the possibility that the embedded nature of truth telling in lying may also induce a symmetric switch cost when switching between truth telling and lying. Debey, De Houwer, & Verschuere, (2014a) flanked the questions in an RT-based deception paradigm by distractors that either represented the truthful or deceptive response. Both lying and truth telling were found to be faster and more accurate on truth distractor trials than on lie distractor trials. This finding suggests that whereas truth telling merely requires the activation of the truth, lying can be considered as a two-step process where the first step entails the activation of the truth, based upon which an alternative response can be selected in a second step (see also Walczyk, Roper, Seemann, & Humphrey, 2003). This two-step process implies a certain overlap between the task sets of truth telling and lying, because both task sets involve the crucial process of selecting the truth response. As such, the two-step process of lying not only supports the idea that shifting is required to switch from truthful to deceptive responses within lying but also predicts that on switch trials, the truth response selection process would never have to be inhibited as it would be required for both truth telling and lying. Consequently, switching between truth telling and lying may only involve (1) the parallel activation and inhibition of the same task goals (to lie or to tell the truth; Mayr & Kliegl, 2000) and (2) depending on the task, the inhibition or activation of the same weaker lie response selection process of the lying task set. This may give rise to symmetric rather than asymmetric switch costs.

Our two hypotheses (i.e., symmetric vs. asymmetric switch costs) have contrasting implications with regard to the contribution of task switching to the cognitive cost of lying. Finding an asymmetric switch cost would imply that task-switching processes partially underlie the cognitive cost of lying. More specifically, the higher switch cost for truth telling would make the cognitive cost of lying smaller on switch trials than on repetition trials. In contrast, a symmetric switch cost would correspond to equally large lie effects on switch and repetition trials, and indicate that task switching does not contribute to the cognitive cost of lying.

To test the hypotheses, participants performed the Sheffield lie test (Spence et al., 2001), an RT-based deception paradigm that lends itself well for the study of task switching. In this paradigm, participants answer simple yes/no questions by pressing a key. Simultaneously with the questions, the response labels "YES" and "NO" appear on the screen and their color instructs to lie or to tell the truth. Typically, lie effects are found, showing longer RTs and more errors on lie trials than on truth trials (e.g., Debey, De Houwer, & Verschuere, 2014a; Verschuere et al., 2011). We examined switch costs in two variants of the Sheffield lie test that we have used in previous research (e.g., Debey, Verschuere, & Crombez, 2012; Debey, Ridderinkhof, De Houwer, & Verschuere, 2014b). These variants differ in the type of questions that are presented. In a first experiment, we reanalyzed a previous dataset in which the switch/repetition ratio was balanced (cf. Debey, Ridderinkhof, De Houwer, & Verschuere, 2014b; Experiment 2). In this experiment, the questions were related to recently performed activities (e.g., "Did you draw a triangle?"). With the aim to replicate and generalize the findings of Experiment 1, we ran a second experiment in which participants answered questions that were related to neutral autobiographical facts about the participant and his/her context (e.g., "Are you a student?").

Experiment 1

Method

Participants

Thirty-six undergraduate students (19 men; $M_{age} = 18.83$ years, SD = 1.16) at Ghent University were recruited. For their participation, which lasted an average of 40 min, they were reimbursed with €5.

Apparatus

The Sheffield lie test was presented on a Pentium IV personal computer with 17-inch color monitors running Tscope (Stevens, Lammertyn, Verbruggen, & Vandierendonck, 2006). Participants sat approximately 50 cm from the computer screen.

Stimuli

The stimuli in the Sheffield lie test were 20 yes/no questions that were related to activities participants had (not) performed in the lab before taking the test (see Appendix 1; Debey et al., 2012). Half of the questions referred to activities participants had performed and required a truthful "yes" response, whereas the other half concerned activities that had not been executed and required a truthful "no" response.

Procedure

Participants were tested one by one. After giving their informed consent, participants performed 10 simple activities in the lab. These activities were selected from a set of 20 activities, and participants were semi-randomly assigned to one of the four conditions with predetermined selections of activities. To verify whether participants remembered which activities they had performed, they subsequently completed a computer task that required to categorize all possible 20 activities as performed or not performed. After this memory check, participants executed the Sheffield lie test. The questions were presented in white in the middle of a black screen (Arial, 28 pt., bold). Participants were instructed to answer as quickly and as accurately as possible by pressing the left ("4" key) or right key ("6" key) on the numeric pad of an AZERTY keyboard. Simultaneously with the questions, the response labels "YES" and "NO" were presented according to their response mapping (counterbalanced across participants; Arial, 28 pt., bold). Their color varied across trials: One color (e.g., blue) instructed to tell the truth, whereas the other color cued to lie (e.g., yellow; counterbalanced across participants). Participants had 5 s to respond. When no response was given within the response deadline, the next question was automatically presented. The response–stimulus interval was set at 300 ms. There were eight trial types, defined by the crossing of three variables: Deception (Truth vs. Lie), Transition (Repetition vs. Switch), and Response (Yes vs. No). A total of 644 questions were presented in a pseudo-random order so that (1) each trial type was preceded and followed by each trial type equally often, and (2) no more than three sequential task repetitions or switches occurred. This resulted in an approximate task switch/repetition ratio of .50. The test consisted of four blocks, separated by a self-paced break. Before the test phase, participants performed a practice phase of 12 trials.

Results

Two participants were excluded from the analyses: One participant because her total error percentage ($M = 12.19$ %) exceeded the group mean ($M = 5.53$ %, SD = 2.41) by 2.5 standard deviations (SDs), and one participant because her mean RT (M = 2,168 ms) deviated more than 2.5 SDs from the group mean ($M = 1{,}481$ ms, SD = 261). Mean error percentages and RTs were subjected to a 2 (Deception: Truth vs. Lie) × 2 (Transition: Repetition vs. Switch) repeated measures ANOVA.[1] We

[1] As we used a different outlier technique in the study of Debey, Ridderinkhof, De Houwer, & Verschuere (2014b), the results slightly differ between the studies.

Table 1 Error rates (%) in the Sheffield lie test of Experiment 1

	Total *M* (SD)	Repetition *M* (SD)	Switch *M* (SD)	Switch cost *M* (SD)/*d*
Truth telling	3.50 (1.40)	2.11 (1.30)	4.88 (2.32)	2.77 (2.52)/*1.10*
Lying	6.91 (3.02)	4.99 (2.61)	8.82 (4.42)	3.83 (4.01)/*0.96*
Lie effect (lie − truth)/*d*	3.41 (2.42)/*1.41*	2.88 (2.70)/*1.07*	3.94 (3.34)/*1.18*	

d refers to Cohen's effect size *d*. Cohen (1988) proposed 0.20, 0.50, and 0.80 as thresholds for small, moderate and large effects

Table 2 Reaction times (ms) in the Sheffield lie test of Experiment 1

	Total *M* (SD)	Repetition *M* (SD)	Switch *M* (SD)	Switch cost *M* (SD)/*d*
Truth telling	1,408 (221)	1,255 (190)	1,573 (274)	318 (157)/*2.02*
Lying	1,551 (237)	1,378 (215)	1,729 (286)	351 (180)/*1.94*
Lie effect (lie − truth)/*d*	143 (146)/*0.98*	123 (158)/*0.77*	156 (189)/*0.83*	

calculated Cohen's effect size *f* using the following formula: $f = \sqrt{[\eta_p^2/(1 - \eta_p^2)]}$. Cohen (1992) considered values from 0.10, 0.25, and 0.40, as small, medium, and large effects, respectively. Because one of our hypotheses predicted a null finding (i.e., a similar switch cost for lying and truth telling), we calculated the JZS-Bayes factor in case a non-significant Deception by Transition interaction suggested that the switch costs of truth telling and lying did not differ in size. The JZS-Bayes factor gives the probability of evidence that the null hypothesis is true (Rouder, Speckman, Sun, Morey, & Iverson, 2009). JZS-Bayes factors were calculated based on paired *t* tests of the truth telling and lying switch costs, and interpreted using the terminology of Jeffreys (1961). Jeffreys considered values smaller than 1, between 1 and 3, and between 3 and 10, to respectively designate 'no evidence', 'anecdotal evidence', and 'substantial evidence' for the null hypothesis.

Errors

Mean error percentages were analyzed after removing the first trial of each block (0.62 % of the total data set), trials with RTs shorter than 300 ms (0.05 %), and trials with no response within the response deadline of 5 s (0.83 %). The main effect of Deception, $F(1, 33) = 67.10$, $p < .001$, $f = 1.42$, pointed to an error lie effect, with more errors made on lie trials than on truth trials (see Table 1). The main effect of Transition, $F(1, 33) = 47.11$, $p < .001$, $f = 1.19$, revealed a higher error rate on switch trials ($M = 6.85$ %, $SD = 3.11$) than on repetition trials ($M = 3.55$ %, $SD = 1.56$). The Deception by Transition interaction, $F(1, 33) = 2.85$, $p = .10$, $f = 0.29$, showed that this switch cost tended to be larger for lying than for truth telling. The JZS-Bayes factor was 1.97, which means that there is anecdotal evidence that this is a null effect.

Reaction times

Reaction times were analyzed after removal of trials on which an error occurred (5.44 %), trials following an error (6.03 %), and truth and lie trials with RTs that deviated more than 2.5 SDs from the individual's mean latency on truth and lie trials, respectively (2.87 %). A significant lie effect was present, as revealed by a main effect of Deception, $F(1, 33) = 30.24$, $p < .001$, $f = 0.96$ (see Table 2). The main effect of Transition, $F(1, 33) = 188.85$, $p < .001$, $f = 2.39$, disclosed the presence of a switch cost with longer latencies on switch trials ($M = 1{,}650$ ms, $SD = 264$) than on repetition trials ($M = 1{,}315$ ms, $SD = 187$). The non-significant Transition by Deception interaction, $F(1, 33) = 1.13$, $p = .30$, showed that this switch cost did not differ for truth telling and lying. Substantial evidence for this null finding was reflected in a JZS-Bayes factor of 4.38.

Discussion

Using an RT-based deception paradigm, we investigated the impact of task switching on truth telling and lying. A tendency toward a larger error switch cost for lying than truth telling was found, resulting in a trend toward a larger error lie effect on switch trials than on repetition trials. The fact that a Bayesian statistical test indicated that there was anecdotal evidence for this effect to be a null finding, casts doubt on the reliability of such a reversed asymmetry. In reaction times, no difference was found between the switch costs for truth telling and lying, making for equally large lie effects on repetition and switch trials. A Bayesian test confirmed the reliability of this null effect. Overall, the experiment suggests that task switching does not account for the cognitive cost of lying, at least not in a design where

Table 3 Mean error percentages (%) in the Sheffield lie test of Experiment 2

	Total M (SD)	Repetition M (SD)	Switch M (SD)	Switch cost M (SD)/d
Truth telling	5.50 (3.09)	3.10 (2.43)	7.89 (4.31)	4.79 (3.28)/*1.51*
Lying	8.50 (4.36)	6.10 (3.81)	10.91 (5.76)	4.81 (4.38)/*0.51*
Lie effect (lie − truth)/d	3.00 (2.84)/*1.06*	3.00 (2.81)/*1.07*	3.02 (4.33)/*0.70*	

Table 4 Reaction times (ms) in the Sheffield lie test of Experiment 2

	Total M (SD)	Repetition M (SD)	Switch M (SD)	Switch cost M (SD)/d
Truth telling	1,333 (161)	1,210 (144)	1,467 (196)	257 (115)/*2.23*
Lying	1,521 (199)	1,395 (180)	1,647 (227)	252 (107)/*2.36*
Lie effect (lie − truth)/d	188 (112)/*1.67*	185 (108)/*1.72*	180 (154)/*1.17*	

truth telling and lying are balanced according to a repetition/switch ratio of .50. To ascertain that these conclusions are not restricted to the specific variant of the Sheffield lie test used in Experiment 1, we tried to replicate and generalize our findings using a different variant of the test in Experiment 2.

Experiment 2

Method

Fifty-three undergraduate students (18 men; $M_{age} = 20.42$ years, SD = 2.11) at Ghent University participated in the study that took about 30 min. In return for their participation, they received €4. The methodology and procedure of Experiment 2 were similar as in Experiment 1, except for the following changes. The stimuli in the Sheffield lie test were 20 yes/no questions related to neutral autobiographical facts about the participant and his/her context (see Appendix 2). Half of the questions required a truthful "yes" response, the other half a truthful "no" response. The experiment was run in groups up to three participants. After providing informed consent, participants performed the Sheffield lie test.

Results

We excluded one participant from the analyses because her total error percentage ($M = 36.62$ %) exceeded the group mean ($M = 7.58$ %, SD = 5.33) by more than 2.5 SDs, and one participant because his mean RT ($M = 2{,}159$ ms) deviated more than 2.5 SDs from the group mean ($M = 1{,}435$ ms, SD = 200). Mean error percentages and RTs were subjected to a 2 (Deception: Truth vs. Lie) × 2 (Transition: Repetition vs. Switch) ANOVA.

Errors

Errors were analyzed after exclusion of the first trials of each block (0.65 % of the total dataset), trials with RTs faster than 300 ms (0.03 %), and trials with no response within the response deadline of 5 s (0.68 %). A significant main effect of Deception, $F(1, 50) = 57.03$, $p < .001$, $f = 1.07$, revealed an error lie effect with more errors made on lie trials than on truth trials (see Table 3). The main effect of Transition also proved significant, $F(1, 50) = 120.14$, $p < .001$, $f = 1.55$, and showed a higher error rate on switch trials ($M = 9.40$ %, SD = 4.60) than on repetition trials ($M = 4.60$ %, SD = 2.87). As suggested by a non-significant Deception by Transition interaction, $F < 1$, this switch cost was equally large for truth telling and lying. The JZS-Bayes factor was 9.12, which gives substantial evidence for the null hypothesis.

Reaction times

For the RT analysis we excluded trials on which an error occurred (7.77 %), trials following an error (8.29 %), and truth and lie trials with RTs that were more than 2.5 SDs removed from the individual's mean truth and lie latency, respectively (2.75 %). As indicated by a significant main effect of Deception, $F(1, 50) = 134.24$, $p < .001$, $f = 1.64$, an RT lie effect was present with longer latencies on lie trials than on truth trials (see Table 4). Also the main effect of Transition reached significance, $F(1, 50) = 449.41$, $p < .001$, $f = 3.00$, and indicated that participants were slower on switch trials ($M = 1{,}559$ ms, SD = 198) than on repetition trials ($M = 1{,}300$ ms, SD = 153). This switch cost did not differ for truth telling and lying, as shown by a non-significant Deception by Transition interaction, $F < 1$. With a JZS-Bayes factor of 8.91, we obtained substantial evidence in favor of this null effect.

Discussion

Using different questions, Experiment 2 replicates and generalizes the findings of Experiment 1. In both errors and RTs, we found that the switch costs for truth telling and lying did not differ in size. Bayesian statistical tests indicated that these null effects should be taken seriously. As a result, we can conclude that the lie effects were equally large on repetition and switch trials. Experiment 2 thus confirms that task switching does not affect the cognitive cost of lying in a balanced design.

General discussion

The executive function of shifting has often been considered relevant in the act of lying (Christ et al., 2009; Visu-Petra et al., 2013). Yet, to date, only a limited number of studies have investigated the role of shifting in deception, thereby mainly highlighting mental set shifting. The fact that another type of shifting—namely task switching—would be needed to efficiently switch between truth and lie trials, has been largely ignored. Because most deception paradigms do not balance truth and lie trials over repetition and switch trials, task switch costs may affect the neurological and behavioral cognitive cost of lying, as reflected in higher prefrontal activity and slower and more error-prone responding compared to truth telling. Moreover, if switching differentially affects truth telling and lying, switch costs may also shape the cognitive cost of lying in balanced designs.

The current study therefore examined the relative size of the behavioral switch cost for truth telling and lying. In an RT-based deception task, participants answered simple yes/no questions related to activities participants had (not) performed in the lab (Experiment 1) or neutral autobiographical facts (Experiment 2). Two hypotheses were contrasted against each other: The asymmetric switch cost hypothesis departed from the interference view on switch costs (Allport et al., 1994), and predicted a larger switch cost for truth telling than for lying as a result of a stronger inhibition of the more dominant truth telling task set on preceding lie trials. In contrast, the symmetric switch cost hypothesis was based on the two-step hypothesis of lying (Debey, De Houwer, & Verschuere, 2014a), and reasoned that the overlapping, crucial truth response selection process between the truth telling and lying task set would preclude its suppression on task switches, and consequently lead to equally large switch costs for truth telling and lying. In both experiments, the error and RT switch costs for truth telling and lying were symmetric. We note that there was a tendency for a larger error switch cost for lying in Experiment 1, but the non-significance and selectivity of the effect refrain us from further interpretation. Moreover, Bayesian statistical tests indicated that the critical null effects in the RT data of Experiment 1 and the RT and error data of Experiment 2 should be taken seriously.

Although our findings suggest that there is no inhibition of the dominant truth response selection process (inherent to both the truth telling and lying task set) when switching between truth telling and lying, inhibition may have played at other levels. First, irrespective of a task switch, the two-step hypothesis of lying implies that the truth response (i.e., the *outcome* of the truth response selection process in a first step, that provides the basis for the subsequent selection of the lie response) has to be inhibited at some point in time because it can start hampering the selection or execution of the lie response if the truth response remains activated (see also the response inhibition hypothesis explained in the Introduction). Using the delta-plot method (Ridderinkhof, 2002), our lab has indeed found evidence for the idea that response inhibition is required to lie in the Sheffield lie test (Debey, Ridderinkhof, De Houwer, & Verschuere, 2014b). Second, when switching between truth telling and lying, the previously activated task goal may need to be inhibited (Mayr & Kliegl, 2000). Our study suggests that this task goal inhibition would impact equally strong on the switch cost for truth telling and lying. Third, when switching from lying toward truth telling, the lie response selection process of the lying task set may have to be inhibited. Our findings show that the inhibition of this selection process on switch truth trials would be equally effortful as the activation of the process on switch lie trials.

Our study has both theoretical and practical implications. First, it adds to the list of studies that did not find an asymmetric switch cost with tasks of unequal strength. The observed switch cost symmetry is consistent with the prediction based on the two-step nature of lying, and as such supports the idea that truth telling forms an important first step in the lying process. Because the truth telling task set overlaps with the lying task set, rather than interfere with it, our findings are in line with Yeung and Monsell's (2003a) statement that asymmetric switch costs will only arise when the interference between task sets is maximized. To strengthen our explanation, it may be interesting to see whether symmetrical switch costs also emerge with other tasks that have similar interwoven properties. Interestingly, a similar reasoning may also account for the findings of Costa and Santesteban (2004). In their study, proficient bilinguals showed a symmetric switch cost when they switched between their two dominant languages (L1 and L2) in a picture-naming task but also when they switched between their first language (L1) and a much weaker language (L3). The authors argued that proficient bilinguals may develop a language-specific selection mechanism to shift between languages which no longer requires inhibitory control of non-selected languages. This mechanism would be functional irrespective of the level of proficiency of the language. Though tentative, we think the symmetric switch cost observed between L1 and L3 may also be explained from a two-step account. It has been claimed that when a language is not well established yet, its lexical representations are activated through translation from the first language (Kroll & Stewart, 1994). This suggests that naming in a weak language may involve a two-step process, where the lexical representation of the strong language is retrieved in a first step, and translated into the weak language in a second step. The fact that the L1 and L3 task set would overlap with regard to the crucial process of strong language retrieval may then account for the observed symmetry in switch costs.

We note here that two-step processes remain highly unexplored in the field of cognitive psychology, despite the fact that they bring about different dynamics than single-step processes. Researchers would merit from drawing up an inventory of cognitive paradigms and behaviors that (may) entail a two-step process, and systematically compare its dynamics. The procedure of the stop-change paradigm (Verbruggen & Logan, 2009), for example, can be considered as a two-step process that bears resemblance with the two-step process of lying. Similar to the stop-signal task, the stop-change paradigm requires participants to inhibit their response to a primary task (i.e., go1 task) following a stop signal. However, participants additionally replace this inhibited response with a response for the second task (i.e., go2 task). Though the implementation of the go2 task has varied, some studies instructed to press the opposite key than required in the go1 task (e.g., Nachev, Wydell, O'Neill, Husain & Kennard, 2007), or any key that had not been used in the go1 task (e.g., Logan & Burkell, 1986). These task procedures resemble the lying process in that the response in the second step (go2 response) has to be selected based on the stopped response generated in the first step (go1 response).

Due to the symmetry of switch costs, the lie effects were equally large on repetition and switch trials. This demonstrates that in a design where the repetition/switch ratio is .50 for both truth telling and lying, task switching does not affect the cognitive cost of lying. However, in largely unbalanced designs, task-switching processes may easily affect the cognitive cost of lying. A look at Tables 1, 2, 3 and 4, for example, suggests that when a task design contains relatively more repetition truth trials and switch lie trials, the lie effects (see difference between switch lie and repetition truth values) may be larger than when a design has more switch truth trials and repetition lie trials (see difference between repetition lie and switch truth values). On that note, it seems plausible that task switching may have shaped the results of two recent studies that manipulated the proportion of truth and lie trials in a Sheffield lie test (Van Bockstaele et al., 2012; Verschuere et al., 2011). Compared to a condition with an equal number of truth and lie trials, the error and RT lie effects were larger in the frequent truth condition (75 % truth trials, 25 % lie trials) and smaller in the frequent lie condition (25 % truth trials, 75 % lie trials). Next to an explanation in terms of an oddball effect and goal neglect (see Van Bockstaele et al., 2012, for a detailed discussion), Van Bockstaele and colleagues also set out the possibility that task-switching processes may drive the proportion effect. The larger proportion of truth trials in the frequent truth condition increased the probability of truth trials being repetition trials and lie trials being switch trials. In the frequent lie condition, on the other hand, lie trials were more likely to involve a repetition and truth trials a switch. As such, switch costs on lie trials in the frequent truth condition and on truth trials in the frequent lie condition may, respectively, have led to an amplification and reduction of the lie effects. Moreover, as switch costs have found to increase with decreasing switching probability (Monsell & Mizon, 2006), the proportion effect may have been boosted by the fact that the frequent lie and truth conditions had an overall lower switching probability than the fifty–fifty condition. Interestingly, the RT-CIT is also characterized by an unequal proportion of deceptive (probe) items and truthful (irrelevant) items. Usually, the probe–irrelevant ratio is 1:4, which is comparable to the proportion in the frequent truth condition in the studies discussed above. It is therefore not unlikely that task-switching processes may partially account for the typically longer RTs and higher error-proneness on probe trials compared to irrelevant trials.

Our findings suggest that researchers who aim to obtain a correct measure of the cognitive cost of lying would be well advised to balance truth and lie trials over switch and repetition trials. In cases where an unbalanced repetition/switch ratio characterizes the task (e.g., Concealed Information Test), it may be informative to explore the data for repetition and switch trials separately. Separating the analysis for repetition and switch trials is definitely warranted in studies that examine the role of mental set shifting within lying, as its contribution should be disentangled from task-switching processes. However, from a practical point of view, unbalanced designs may be applied strategically in order to boost the cognitive cost of lying.

The presence of switch costs in a deception context puts some studies that investigated mental set shifting in deception into a new light. The correlation between truth telling performance and the shifting task in the study of Visu-Petra and colleagues (Visu-Petra, Miclea, & Visu-Petra, 2012) may point to the role of task switching on truth switch trials, and suggests that the correlation between deception and the shifting task may not only reflect mental set shifting during deception but partially also task-switching processes on deceptive switch trials. Though tentative, Christ et al.'s (2009) finding of only minor overlap between brain regions linked to shifting and regions that are more strongly activated during lying than during truth telling may have been confounded by task switching activation that is present on both truth and lie switch trials.

Finally, we propose one tentative way how task switching may provide a cue to detect deception in real-life situations. Our results point to the fruitfulness of mixing crime/alibi-related questions (e.g., "Did you kill your mother-in-law?") with neutral questions (e.g., "Are you in Belgium?") in interrogations (see Control Question Technique; Ben-Shakhar, 2001). We can assume that innocent suspects will tell the truth on both question types. Guilty suspects, however, will lie to questions related to their crime or fake alibi, whereas they will be forced to tell the truth to neutral questions. In sum, only guilty suspects will switch between truth telling and lying. As a result, we could expect to find differences between guilty and innocent suspects when comparing (1) crime-related questions following a neutral question with crime-related questions following another crime-related question, and (2) neutral questions following a crime-related question with neutral questions following another neutral question.

In conclusion, our study revealed that switching between truth telling and lying comes with an equally large switch cost for truth telling and lying. This finding can be explained from the assumption that lying is a two-step process that involves a first step of truth telling, and demonstrates that task-switching processes do not bore responsibility for the cognitive cost of lying. However, we stress that task switching may have a significant impact upon the cognitive cost of lying when truth and lie trials are not balanced according to a repetition/switch ratio of .50. We therefore hope that our findings will stimulate researchers and practitioners to optimize their task designs and interrogations. Future work should determine which components of deception settings influence switching between truth telling and lying. This will help to establish the boundary conditions of using switch costs as a means to detect deception.

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Appendix 1

See Table 5.

Table 5 Questions used in Experiment 1

Did you move a flowerpot?
Did you take a picture?
Did you roll up a rope?
Did you hang a poster?
Did you sharpen a pencil?
Did you rip a piece of paper?
Did you blow a balloon?
Did you draw a triangle?
Did you tighten a screw?
Did you cut out an article?
Did you toss a coin?
Did you dust?
Did you put a stamp?
Did you use a flashlight?
Did you lit a candle?
Did you fold a towel?
Did you pick up a needle?
Did you make a jigsaw?
Did you leaf through a book?

Because participants were assigned to one of four conditions that differed with regard to the activities that had to be performed, the truthful answer to the questions depends on the condition

Appendix 2

See Table 6.

Table 6 Questions used in Experiment 2

Questions that required a truthful "yes" response	Questions that required a truthful "no" response
Are you taking part in an experiment?	Are you having a bath?
Are you sitting on a chair?	Are you lying on a bench?
Are you in Ghent?	Are you in Antwerp?
Are you sitting in front of a computer?	Are you sitting in front of a television?
Are you a student?	Are you a professor?
Are you younger than 50?	Are you older than 50?
Are you awake?	Are you asleep?
Do you speak Dutch?	Do you speak Serbian?
Are you at the faculty of Psychology?	Are at the faculty of Medicine?
Are you inside?	Are you outside?

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