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Who did I lie to that day? Deception impairs memory in daily life

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Abstract

Research has demonstrated that deceptive responses can undermine item and source memories. However, previous studies have often randomly assigned participants to an honest or deception group and asked them to respond in specific ways in an interview, rather than providing them a choice of what response to give. Moreover, little attention has been given to destination memory in previous research. Using a daily life paradigm, we investigated the effects of deception on memory. After completing a mock shopping task, participants were told that someone would ask them questions about their shopping lists. The participants voluntarily chose to tell the truth or lie in the interview and were encouraged to respond as they would in their daily lives. An item memory test, source memory test and destination memory test were given 48 h after the interview. Source and destination memories but not item memories were impaired for participants who chose to lie. Specifically, liars forgot the things about which they lied and mistakenly believed that they lied about many things that they did not, and they also did not remember to whom they lied. We conclude that deception can disrupt memory in daily life.

Introduction

Deception, or lying, is a kind of behavior in which individuals attempt to deliberately mislead other people in verbal and/or nonverbal ways to gain benefits or avoid losses (Abe, 2009; Masip et al., 2004). It has been found that lying happens every day (DePaulo et al., 1996) and is very common in daily social life (Abe, 2011). However, there is no doubt that deception has consequences, especially if it disrupts memories (Pickel, 2004).

The effects of deception on memory have been widely studied in recent years (Battista et al., 2021a; Geven et al., 2020; Haj et al., 2017; Paige et al., 2019; Romeo et al., 2019a, b). Studies in this field typically follow a standard procedure. First, participants are randomly assigned to an honest or deception group and are asked to complete a baseline memory test after watching a video or performing an action. Then, the participants are asked to respond honestly (honest group) or provide deceptive responses (deception group) in an interview. One or more days after the interview, all participants are required to respond honestly in the final memory tests, which often include an item memory test and a source memory test. Comparisons of the final memory tests between groups are then conducted to determine the effects of deception on memory. Researchers have typically found that participants in the deception group perform worse in the final memory tests than those in the honest group, suggesting that deception impairs memory of the items and/or interview (Mangiulli et al., 2018; Otgaar et al., 2020; Romeo et al., 2019a; Schreckenbach et al., 2020). It has also been suggested that deception causes more nonbelieved memories than honesty (Battista et al., 2020, 2021a; Otgaar et al., 2014a, 2016a; Polage, 2017).

Based on findings in this field, Otgaar and Baker (2018) proposed a memory and deception (MAD) framework to explain the effects of deception on memory. In their framework, three types of deception were classified based on the nature of the lie: false denial (denying events or details of events that happened), feigning amnesia (claiming to lose memories of events or details of events that are remembered), and confabulation (fabricating events or details of events that did not happen) (Otgaar & Baker, 2018). In addition, they argued that different types of deception differ in the degree of cognitive resources used. For example, few cognitive resources are required for false denial and feigning amnesia, whereas confabulation requires many more cognitive resources. They also postulated that lying strategies that

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do not require many cognitive resources could lead to omission errors because of a lack of rehearsal. In contrast, elaborate lies such as confabulation that require more cognitive resources may be subject to source monitoring errors and result in false memories or memory distortions (Otgaar & Baker, 2018). In summary, it has been suggested that deception requires cognitive resources, and different deceptive strategies requiring different degrees of cognitive resources could result in different memory impairments (Otgaar & Baker, 2018).

Several important issues, however, have not been considered in previous studies. The most important issue concerns the definition of deception. Deception is a deliberate action that serves some purposes, and intentionality is the first element of deception (Masip et al., 2004). Deception involves basic components, such as the decision to deliberately construct a deception (Walczyk et al., 2014). With a decision to deceive, some information will be activated from long-term memory by the social context, and this information will guide the evaluation of the possible cost of truth-telling and the benefits of deception (Walczyk et al., 2016). In other words, the decision to deceive is a process of weighing benefits and costs, and deception itself is a motivated and intentional behavior of pursuing benefits or avoiding losses. In previous studies, however, participants did not decide to lie by themselves but were asked to lie and provide specific responses, such as "I cannot remember …" or "No, I did not see …" (e.g., Battista et al., 2021a; Otgaar et al., 2016a, 2018, 2020; Romeo, et al., 2019a, b). Therefore, the deception studied in previous research does not accord with the definition of deception.

One may argue that asking participants to tell lies in specific ways is necessary and is the only feasible way to investigate the effects of deception on memory in laboratory research. However, the procedure used in previous studies violated the definition of deception and resulted in some limitations in ecological validity. Ecological validity refers to the degree to which experimental measures (i.e., settings, materials and behaviors) naturally occur and represent events that occur in daily life (Brewer, 2000; Rotheram-Fuller, 2013). In studies of deception, to improve ecological validity, a social context that will naturally induce deceptive behavior should be provided (Marcel et al., 2015). However, deceptive behaviors in previous studies did not naturally occur but were artificially constructed to satisfy the experimenters' needs. Participants in previous studies were not given a chance to make deliberate decisions and respond in their typical manner, and they did not deceive for any benefit. These shortcomings indicate that the type of deception studied in previous research was instructed and not intentional deception. It has been argued that studies using instructed deception paradigms did not actually investigate deception because they eliminated the voluntary intention to deceive and its deliberate execution (Sip et al., 2008). The memory effects observed in previous studies might have resulted from demand characteristics (Romeo et al., 2019b). Therefore, ecological validity could have been undermined by the instructed deception paradigm used in previous studies. These previous studies were well-designed experiments in applied cognitive psychology research, but their ecological validity is limited.

Previous studies have focused on the effects of deception on memory, especially on item memory and source memory. However, far too little attention has been given to destination memory. Destination memory, or target memory, is related to a person remembering to whom they have previously delivered information (Marsh & Hicks, 2002). A liar needs to remember to whom they lie to avoid inconsistencies and maintain deception (Haj et al., 2018). A positive and significant correlation between destination memory and the ability to deceive has been reported (Haj et al., 2017). It was also found that participants with high deception scores (who received more than 6 points on the deception scale) had better destination memories for both true and false information than those with low deception scores (who received less than 6 points on the deception scale) (Haj et al., 2018). However, it remains unclear whether the act of deceiving itself affects destination memory. To better understand the effects of deception on memory, destination memory was considered in the present study.

This study aimed to develop a better understanding of the effects of deception on memory. An investigation was conducted to examine whether the deception effects obtained in laboratory-based deception research were also true in a real-world situation. To our knowledge, this was the first study extending this issue to daily life, and its results may facilitate a better understanding of the effects of deception on memory. We also focused on destination memory, which is necessary and important for liars to avoid being caught. Belief and memory ratings were also recorded to investigate whether nonbelieved memories were created more often by deceptive responses. Comparisons of item memory, source memory, destination memory, and belief and memory ratings were conducted. With the study results, we believe that we can more fully understand the effects of deception on memory.

A daily life paradigm was used to improve the ecological validity of the present study. Participants were asked to complete a mock shopping task. After shopping, the participants were told that two people with no idea what they bought would ask them questions about their shopping lists in an interview. The participants were informed they could choose whether to answer the questions honestly or to provide deceptive responses. Moreover, regardless of whether the participants chose to tell the truth or deceive, they were encouraged to respond as they would their daily lives. A

baseline memory test was conducted before the interview. The participants were asked to complete an item memory test, source memory test, and destination memory test 48 h after the interview. Based on previous studies demonstrating that lying could cause more memory disruptions than telling the truth could (Mangiulli et al., 2018; Otgaar et al., 2020; Romeo, et al., 2019a; Schreckenbach et al., 2020), we expected worse memory performances in all memory tests (with the exception of the baseline memory test) by participants who chose to lie in the interview.

Method

Participants

Using G*Power (Faul et al., 2007; version 3.1.9.7), a prior analysis with power of 0.8 and an effect size ($f = 0.4$) based on a previous study from Haj and his colleagues (2018) suggested a minimum sample size of 52 participants. Fifty-seven adults (6 male) aged 18–25 years ($M = 20.66$ years, $SD = 1.62$) were recruited from Tianjin Normal University. All participation was voluntary, and participants provided informed consent in accordance with the principles of the Helsinki Declaration. They were paid for participating.

Design and procedure

A single-variable design was used in the present study. After completing the shopping task, the participants were told that they could choose to tell the truth or lie in the interview, and they were naturally divided into two groups based on their choices. Therefore, the independent variable was the group (honest group or deception group). The participants were asked to complete several memory tests in this study. Thus, the dependent variables were the responses in the memory tests.

A small store was set up in a room on the first floor. Twenty products were offered for sale: bottled drinking water, chewing gum, cookies, instant coffee, seaweed, bread, strawberry pie, instant noodles, chocolate, coke, tissue, soap, toothpaste, toothbrush, towel, garbage bags, hangers, laundry detergent, N95 masks, and cotton swabs.

The participants took part individually. All participants were asked to complete a mock shopping task and buy ten goods from the store as they usually would in the supermarket. There was no time limit for shopping. After shopping, the participants were asked to scan a QR code and complete a mock payment using their smartphones, although they did not pay any money.

After shopping, the participants engaged in a distractor task (playing Tetris) for 5 min. Then, a baseline memory test was given. In this test, the participants were asked to complete a free-recall task and write down the items that they bought. The participants were also instructed to indicate their belief (How strong is your belief that you bought this item: 1 = *no belief*, 8 = *strong belief*) and memory (Do you actually remember that you bought this item: 1 = *no memory at all*, 8 = *clear and complete memory*) ratings for each item. The scales used were derived from the Autobiographical Belief and Memory Questionnaire (Scoboria et al., 2004, 2014). Then, the participants engaged in another 5-min filler task (playing Tetris).

The participants were then told that two people on the second floor, who had no idea what items they bought, wanted to ask them questions about their shopping lists. The participants were also instructed that they could choose to answer all of the questions honestly or deceptively, and they were encouraged to respond as they would in their daily lives. They were informed that they would be paid 29 (for telling the truth) or 35 (for lying) yuan for their participation.

The participants were taken to a room on the second floor after making the choice. Before they entered the room, the participants were asked to respond as accurately as possible based on their choices. There were two people (both female) in the room. The interviewers were strangers to the participants and had obtained the participants' shopping lists when they were completing the baseline memory test. Ten items were prepared for the interview: five items were randomly selected from the participants' shopping lists, and five items were not sold in the store. The interviewers alternately asked questions using a fixed question structure "Did you buy XXXX?" The participants who chose to tell the truth answered all questions honestly, giving positive responses to questions concerning the items on their shopping lists and negative responses to questions concerning the items that were not sold in the store. On the other hand, the participants who chose to tell lies gave deceptive answers to all the questions, giving negative responses to questions concerning the items on their shopping lists and positive answers to questions concerning the items not sold in the store. Thus, according to the way of deception, the participants chose to tell lies, gave false denial responses to the items on their shopping lists and gave confabulation-type responses to the items not sold in the store. To improve the ecological validity, the participants could determine the content of their answers.

Liars may experience negative emotions, such as nervousness, when they lie (Wielgopolan & Imbir, 2020). Moreover, human emotion and memory interact with each other (Phelps, 2004), and negative emotion has opposing effects on item memory and associative memory (Bisby et al., 2016). To clarify the relationships among lying, emotion and memory, the participants were asked to assess and report their nervousness (1 = *not nervous at all*, 10 = *very nervous*) in the interview. It has been suggested that working memory

Table 1 Mean error rates and belief and memory ratings with correct responses in memory tests for the honest and deception groups

	Baseline memory test		Item memory test		Source memory test		Destination memory test	
	Honest	Deception	Honest	Deception	Honest	Deception	Honest	Deception
Error rates (%)	9.03 (1.73)	10.01 (1.81)	7.05 (1.49)	9.51 (1.81)	22.74 (1.72)	31.21 (2.04)	15.72 (2.11)	43.37 (3.15)
Belief	7.69 (0.04)	7.67 (0.05)	7.40 (0.06)	7.53 (0.06)	6.10 (0.09)	5.62 (0.11)	5.84 (0.15)	4.80 (0.18)
Memory	6.89 (0.09)	7.28 (0.07)	6.01 (0.11)	6.53 (0.10)	5.69 (0.10)	5.71 (0.11)	5.08 (0.14)	4.47 (0.18)

Note. The standard error of the mean is shown in parentheses

capability affects memory (Gerrie & Garry, 2007) and that poor working memory predicts more false memories (Peters et al., 2007). Therefore, to clarify the relationships among lying, working memory capability and memory, we also assessed working memory capabilities using the WAIS-III Digit Span subtest (Wechsler, 1997).

The participants were asked to complete the final memory tests 48 h after the interview. An item memory test, source memory test and destination memory test were consecutively administered. In the item memory test, the participants were instructed to recall what items they bought two days prior and indicate their belief (How strong is your belief that you bought this item: 1 = *no belief*, 8 = *strong belief*) and memory (Do you actually remember that you bought this item: 1 = *no memory at all*, 8 = *clear and complete memory*) ratings for each item. In the source memory test, the participants needed to identify which items about which they had (not) been asked in the interview. Twenty items were included and presented in a random order in the source memory test: five items that the participant bought and were asked about in the interview, five items that they bought but were not asked about in the interview, five items that were not sold in the store but were asked about in the interview, and five items that were not sold in the store and were not asked about in the interview. The participants were also required to indicate their belief (How strong is your belief that you were/were not asked about this item: 1 = *no belief*, 8 = *strong belief*) and memory (Do you actually remember that you were/were not asked about this item: 1 = *no memory at all*, 8 = *clear and complete memory*) ratings for each item. In the destination memory test, to determine the destination memory scores, the participants were required to point out who had asked them about particular items during the interview using two photos of the interviewers. The participants were also asked to indicate their belief (How strong is your belief that this is the person who asked you about this item: 1 = *no belief*, 8 = *strong belief*) and memory (Do you actually remember that this is the person who asked you about this item: 1 = *no memory at all*, 8 = *clear and complete memory*) ratings for each item.

After completing the final memory tests, the research purpose was explained to the participants. They were also informed that we provided benefits to the participants who chose to lie for the consideration of ecological validity and that we did not encourage lying.

Results

It has been suggested that not all data (such as variation with respect to participants and items) are considered in *t* tests; therefore, *t* tests lose statistical power and do not generalize well to more complex models (Schad et al., 2020). Therefore, we used the lme4 package (Bates et al., 2015) to analyze all data from this study in R (R Development Core, 2016). A linear mixed-effects model (LMM) was used to analyze belief and memory ratings for correct responses, and a generalized linear mixed-effects model (GLMM) was used to analyze response accuracy, with items and participants as crossed random effects (Baayen et al., 2008). In the LMM and GLMM, the honest group was coded as 0.5, and the deception group was coded as −0.5; thus the deception group was taken as the reference in the analyses.

All participants in the present study were naturally divided into the deception group or honest group, depending on whether they chose to lie or be honest in the interview. Twenty-seven participants (5 males) chose to lie and the others chose to respond honestly (1 male). The belief and memory ratings for the correct responses and response accuracy are shown in Table 1, and the statistical results are shown in Table 2.

Shopping

We recorded the shopping times of the participants, although there were no shopping time limits. We found no significant difference between the honest and deception groups in shopping time (Honest: $M = 124$ s, $SD = 27$; Deception: $M = 119$ s, $SD = 25$; $t = 0.75$, $p > 0.05$).

Baseline memory

As shown in Table 2, no significant differences were found in the free-recall task or belief ratings between the honest and deception groups, suggesting that the participants in both groups similarly recalled the items that they bought and

Table 2 Statistical results for memory tests

	b	*SE*	*z* or *t*	*p*
Baseline memory test				
Error rates	−0.12	0.30	−0.41	0.69
Belief	0.01	0.12	0.10	0.90
Memory	−0.43	0.22	−1.92	0.06
Item memory test				
Error rates	−0.33	0.39	−0.86	0.39
Belief	−0.15	0.17	−0.87	0.39
Memory	−0.50	0.37	−1.35	0.18
Source memory test				
Error rates	−0.47	0.16	−2.90	0.004
Belief	0.45	0.31	1.43	0.16
Memory	−0.03	0.33	−0.09	0.93
Destination memory test				
Error rates	−1.80	0.38	−4.80	< 0.001
Belief	1.04	0.48	2.16	0.04
Memory	0.066	0.43	1.54	0.13

provided similar belief ratings. Marginal significance was found in the memory ratings, suggesting that participants in the deception group rated their memory higher than those in the honest group.

Interview

The participants were asked to respond as accurately as possible based on their choice to lie or be honest in the interview, but many more false responses were observed in the deception group than the honest group (honest: 1 response; deception: 21 responses; χ^2 (1, 570) = 21.2, Cramer's $V = 0.19$, $p < 0.001$), suggesting that participants who chose to lie also mistakenly provided some honest responses. Moreover, no significant differences in the degree of nervousness (honest group: $M = 4.67$, $SD = 2.29$; deception group: $M = 4.63$, $SD = 2.04$; $t = 0.06$, $p > 0.05$) or working memory capabilities (honest group: $M = 14.5$, $SD = 2.53$; deception group: $M = 15.5$, $SD = 2.36$; $t = -1.62$, $p > 0.05$) were found between the honest and deception groups, suggesting that the roles of emotion and working memory capability could be excluded in the present study.

As mentioned above, the honest group gave a deceptive response and the deception group gave twenty-one honest responses in the interview. To clarify the effects of deception on memory, false-response items from the corresponding participants were excluded from the following analyses.

Item memory

As shown in Table 2, no significant differences were found in the free-recall task, belief and memory ratings between the honest group and deception group.

Source memory

A significant difference was found in error rates between the honest and deception groups, suggesting that the deception group lost more memories of the items that were asked about in the interview than the honest group. No other comparisons reached statistical significance.

The data were also separately analyzed based on the items contained in the source memory test. The descriptive statistics are shown in Table 3 and the statistical results are shown in Table 4. We found a significant difference in error rates between the honest and deception groups for items that were on the shopping lists but not asked about in the interview and a marginally significant difference in error rates for items that were not on the shopping lists and not asked about in the interview. These findings suggest that the deception group had higher error rates than the honest group for these items in the source memory test. These items were not asked about in the interview, and given that the participants in the deception group had chosen to lie in the interview, this result pattern suggests that they lost their memories of the items about which they lied in the interview and mistakenly believed that they had lied about items that were not asked about in the interview. Other comparisons did not show statistical significance.

Table 3 Belief and memory ratings for correct responses and mean error rates in the source memory test

Items	Honest			Deception		
	Error rates (%)	Belief	Memory	Error rates (%)	Belief	Memory
Bought and asked about	14.77 (2.92)	6.29 (0.17)	5.91 (0.15)	21.09 (3.62)	6.04 (0.20)	6.08 (0.18)
Bought and not asked about	35.57 (3.94)	5.26 (0.21)	4.74 (0.22)	53.33 (4.31)	4.68 (0.28)	5.02 (0.27)
Not bought and asked about	30.67 (3.78)	6.42 (0.18)	5.96 (0.19)	29.75 (3.94)	5.81 (0.22)	5.93 (0.20)
Not bought and not asked about	10.32 (2.46)	6.27 (0.18)	5.96 (0.19)	20.11 (3.46)	5.64 (0.21)	5.58 (0.21)

The standard error of the mean is shown in parentheses

Table 4 Statistical results for the items in source memory test

	b	*SE*	*z* or *t*	*p*
Bought and asked about				
Error rates	−0.60	0.49	−1.22	0.22
Belief	0.25	0.36	0.70	0.49
Memory	−0.11	0.33	−0.35	0.73
Bought and not asked about				
Error rates	−1.03	0.45	−2.31	0.02
Belief	0.59	0.50	1.17	0.25
Memory	−0.14	0.50	−0.28	0.78
Not bought and asked about				
Error rates	0.03	0.33	0.09	0.93
Belief	0.63	0.38	1.66	0.11
Memory	0.07	0.39	0.19	0.85
Not bought and not asked about				
Error rates	−0.95	0.54	−1.77	0.08
Belief	0.51	0.47	1.07	0.29
Memory	0.17	0.50	0.34	0.74

Destination memory

A significant difference in error rates was found between the deception and honest groups, suggesting that the deception group performed worse in identifying the individual to whom they had lied than the honest group. Differences between the groups in belief ratings but not memory ratings were significant, suggesting that participants who chose to lie were more uncertain about to whom they had responded and lied than those who responded honestly.

Nonbelieved memories

Nonbelieved memories are memories of vividly recollected events for which occurrence is no longer believed (Mazzoni et al., 2010; Otgaar et al., 2014b). It has been suggested that judgments of collection and belief are distinct (Scoboria et al., 2004). Collection can be impacted by internal and cognitive/memory-related processes, and belief can be impacted by internal and external processes and is often strongly mediated by social factors (Scoboria et al., 2014). People often develop nonbelieved memories under certain conditions (Otgaar et al., 2014a) and experience them as "memory-like" (Scoboria et al., 2004). As in previous studies (Clark et al., 2012; Otgaar et al., 2016a), nonbelieved memories were classified as instances when the belief ratings were at least two scale points lower than the memory ratings, regardless of whether the responses were correct or incorrect in the memory tests. For example, a participant reported a memory rating of 8, indicating a strong memory, and a belief rating of 6, indicating a moderate belief score, for an event and this was classified as a nonbelieved memory.

Table 5 Number of nonbelieved memories in the memory tests in the honest and deception groups

	Honest	Deception
Baseline memory test	7	10
Item memory test	3	3
Source memory test	32	26
Destination memory test	12	11

Whether deception created more nonbelieved memories was examined. The number of nonbelieved memories for each group and test is shown in Table 5. Before the analysis, we defined items with nonbelieved memories as 1, and other items were defined as 0. Therefore, a GLMM could be used to analyze the data. No significant differences in nonbelieved memories were found in the baseline memory test ($b = -0.62$, $SE = 0.63$, $z = -0.98$, $p > 0.05$), item memory test ($b = 0.15$, $SE = 1.1$, $z = 0.13$, $p > 0.05$), source memory test ($b = 0.07$, $SE = 0.47$, $z = 0.15$, $p > 0.05$) or destination memory test ($b = -0.01$, $SE = 0.72$, $z = -0.02$, $p > 0.05$), suggesting that the deception group did not create more nonbelieved memories than the honest group.

Discussion

Using a daily life paradigm, the present study adds novel evidence of the effects of deception on memory. It has been suggested that spontaneous responses are honest in a seductive situation (Foerster et al., 2013), and people tend to lie when they are faced with temptations (Abe, 2009; Shalvi et al., 2012). In this study, the participants completed a shopping task without time limits, decided whether to lie or tell the truth in the interview on their own and responded as they would in their daily lives. The numbers of participants who chose to lie and be honest were similar, and participants who chose to lie could obtain more benefits. Based on the definitions of deception and ecological validity, we believe that the ecological validity of this study reached an acceptable level.

Considering the procedure used in the present study, one may argue that there might be some individual differences between the honest and deception groups, resulting in two groups that were not homogeneous. Indeed, individual differences could be well controlled in previous studies by randomly allocating participants to a truth-telling condition or deceptive-response condition. We chose to make a trade-off, however, between ecological validity and the risk of creating heterogeneous groups. First, ecological validity has been highlighted in deception research (Marcel et al., 2015; Sip et al., 2008). Moreover, based on the definition of deception (Abe, 2009; Masip et al., 2004), participants deciding for themselves whether to deceive provide real instances of

deception. Third, no significant differences in error rates and working memory capabilities were found between the honest and deception groups in the baseline memory test, suggesting that both groups were homogeneous in long-term memory and working memory capabilities. One might notice the marginally significant difference in memory ratings in the baseline test, which suggested that the participants in the deception group gave higher ratings regarding their shopping memories. Memory ratings are subjective measures, and memory ratings may be a contributing factor to decision-making. The main reason why these participants decided to lie was that they could obtain benefits from their decision. All participants who chose to lie were asked whether they would have decided to deceive if they were paid equally for their participation to those who chose to be honest, and their answers were negative. None of the participants would have chosen to lie if they did not obtain any benefits, suggesting that gaining benefits was the main reason for lying and that our manipulation has high ecological validity.

It is not easy to lie, even when we deliberately lie and can lie without nervousness. Before the interview, the participants were asked to respond as accurately as possible based on their choices. No participants were nervous during the interview. However, the participants who chose to lie made more mistakes and provided many honest responses to the questions, suggesting that people may accidentally tell the truth when they intend to deceive. The possible reason for the unintentional honesty is that the liars failed to suppress the truth and, therefore, spoke the truth. However, more investigations are needed in the future to examine this possibility.

We found no differences in the item memory test between the honest and deception groups, suggesting that false denial did not impair the liars' item memories. This finding is consistent with some previous studies (Battista et al., 2021a; Romeo et al., 2019b) but inconsistent with others (Otgaar et al., 2020; Romeo, et al., 2019a; Vieira & Lane, 2013). In the present study, the participants were asked to complete a mock shopping task; thus, their degree of involvement was very high. Visual, tactile, and contextual information obtained by the participants during shopping was very helpful for their memories. Therefore, the participants were less likely to forget the items that they bought, regardless of whether or not they chose to lie.

Several interesting findings were obtained in the source memory test. First, liars provided more incorrect responses in the test than those who were honest, suggesting that the liars had more false memories of the interview. Second, no significant differences were found regarding the shopping list items that were asked about in the interview. This observation suggested that no DIF (denial-induced forgetting) effect (Otgaar et al., 2016a) was obtained in the present study, which was inconsistent with previous studies (Otgaar, Howe, et al., 2016a, b, 2018; Romeo, et al., 2019a) but in line with other research (Romeo et al., 2019b). There are two possible explanations for the inconsistency. It has been suggested that the DIF effect may have a boundary and that the effect may disappear if participants are actively involved in an event (Romeo, et al., 2019b). This study provides new evidence for this suggestion. Another possible explanation is related to the way that the liars responded in the interview. To improve the ecological validity, we did not ask the participants to respond in a specific way during the interview. Each could tell the truth or lie in their own way. The participants responded "No" or "No, I didn't buy XXXX" or "No, I didn't" when they gave false denial responses. However, in previous studies (Otgaar et al., 2016a, b, 2018; Romeo, et al., 2019a), a classical false denial strategy in which liars were asked to respond "No, I did not XXXX" was used. Therefore, differences in the false denial strategy between the present study and previous studies may also play an important role in the inconsistency of the DIF effect.

The most interesting finding observed in the source memory test was that the deception group provided more incorrect responses regarding items that were not asked about in the interview. Combined with their decision to lie in the interview, this novel observation means that the participants who told many lies within a short time mistakenly believed that they had lied more than they actually did. False source memories can cause disruptions in daily life since people who make such mistakes are likely to lie more to avoid being caught for the original lie. People might increasingly lie and cause more problems in their lives until they stop lying or are caught lying. Therefore, in daily life, it is dangerous to tell too many lies within a short time, as people can become confused about what lies they have told.

Another novel finding was observed in the destination memory test. The participants in the deception group failed to identify the people to whom they had lied and responded. The error rate was approximately 45% for the participants who chose to lie in the test, suggesting that their response accuracy was not much better than chance in identifying the people to whom they had lied. On the other hand, the participants who chose to tell the truth had less than 20% error rates in the destination memory test, suggesting that their memories relevant to identifying the interviewers were very good and much better than those of the liars. Moreover, we also found that liars were more uncertain about their correct responses in the destination memory test than truth-tellers. A probable explanation is that more cognitive resources were needed by the liars than the truth tellers during the interview. It has been suggested that lying consumes more cognitive resources than telling the truth (Battista et al., 2021b; Otgaar & Baker, 2018). The participants who chose to lie gave deceptive responses to all questions regarding items that were (not) on their shopping lists. Therefore, the participants

in the deception group needed to first distinguish whether they bought the questioned item and then inhibit the truth and provide a deceptive response as accurately as possible. Thus, liars who engaged in attentionally telling lies in the interview required many cognitive resources and did not have enough cognitive resources to remember the people to whom they lied. As a result, they performed poorly in the destination memory test.

Regarding nonbelieved memories, no significant differences were observed in any memory test in the present study, suggesting that deception did not create more nonbelieved memories than telling the truth. This observation is consistent with previous research (Otgaar et al., 2016a), which has suggested that social feedback, rather than self-reporting, is one of the most important variables related to creating nonbelieved memories. As mentioned above, this finding may also result from the high degree of involvement of all participants, as the participants could obtain abundant multisensory information during the tasks.

The present study makes several important contributions to understanding the effects of deception on memory. First, we used a daily life paradigm, which was helpful for improving the ecological validity of our study and further examining the effect of deception on memory in everyday life. We found that deception impairs memory, allowing the results of laboratory studies to be tested and extended to daily life. Moreover, effects of deception on source memory were also found in the present study. People often forgot the things about which they lied and mistakenly thought that they lied about something when they did not. Finally, in addition to item memory and source memory, we took our research a step further to investigate the effect of deception on destination memory, which is important for liars in maintaining their lies. The liars almost forgot to whom they had lied and responded several days prior and were more uncertain about their targets. These observations provide a more complete picture of the effects of deception on memory in daily life.

Our observations also have some theoretical implications. First, the MAD framework suggested that false denial causes more omission errors in events and interviews (Otgaar & Baker, 2018), and the false denial effect in the source memory test was labeled the DIF effect (Otgaar et al., 2016a). The DIF effect appears to be relatively stable and has been found in many studies using many kinds of materials (Battista et al., 2020; Battista et al., 2021a; Otgaar et al., 2016a, b, 2018; Romeo, et al., 2019a). No significant omissions in the item memory test and no DIF effect were observed in the present study. As mentioned above, the degree of involvement and differences in false denial responses may play important roles in such inconsistency. In our latest research, we demonstrated that the DIF effect and the effects of deception on memory could be modulated by the degree of involvement (Li & Liu, 2021). However, we cannot rule out that the DIF effect was caused by the particular way of false denial for now. More research on this issue should be conducted before the association between the DIF effect and the way of false denial can be clearly understood. Second, honesty is the default rule in most cultures, and deception is often considered immoral and as violating the rules. It has been suggested that people may experience cognitive conflict during rule violations (Pfister et al., 2016), and rule violations require more time than rule-based responses (Wirth et al., 2016). In the decision-implementation- mandatory switch-inhibition (DIMI) model (Wirth et al., 2018), the authors have suggested that people may need to first choose whether to follow or break a rule (in this study, whether to be honest or dishonest) and that a violation response (lie) is created by means of inversion (this was the way that liars told lies in the present study), negation or transformation. A conflict may occur when people violate a rule, as between an activated rule-based response and the transformation of the rule-based response (honest and dishonest in this study, respectively). Thus, the rule-based response (to be honest) must be inhibited to allow a successful rule violation (tell lies). Therefore, the effects of deception on memory may result from cognitive conflict during lying and the inhibiting honest responses, and those cognitive processes may undermine liars' memory of the interview. Third, it has been suggested that previous responses given in an intentional context could impact later responses to the same stimulus if the intentional context is repeated, and interdependent associations among the stimulus, the intentional context and responses allow flexible and context-specific retrieval (Pfeuffer et al., 2019). Specifically, when people have an intentional context (telling the truth) and respond (honest responses) to questions (stimulus) in a situation, they may automatically retrieve their previous responses to the same questions when presented with the same intentional context (telling the truth) in another situation. However, people may fail to retrieve their previous responses when the intentional context is inconsistent between different situations. To examine false denial and memory, the participants were asked to tell the truth or lie in an interview, and be honest in the source memory test, which included some items that were (not) asked about in the interview. The intentional context was consistent for the honest group (truth-truth) but not for the deception group (lie-truth) between the interview and source memory test. Thus, the honest group may have successfully retrieved their responses given in the interview during the source memory test, while the deception group could not. This may be another potential mechanism that causes the DIF effect, which should be given more attention. However, the present study did not observe a DIF effect. This may have resulted from the participants in the deception group having a stronger desire to tell lies than those in the honest group, and the degree of intentional context

may have modulated context-specific retrieval. In summary, the way of false denial, the inhibition of rule violation and context-specific retrieval may need to be considered in theoretical explanations and constructions regarding the effects of deception on memory.

Several limitations to this pilot study should be acknowledged. Different from previous studies that have asked participants to lie or be honest and respond in particular ways in the interview, the participants in the present study were allowed to choose to lie or tell the truth and respond in their own ways during the interview. We believe that our design brought some improvements to ecological validity. However, this study also had some limitations in ecological validity. First, people rarely make intentional decisions to lie before conversations, lie to every question in a given situation and receive payment for lies in daily life. Moreover, it has been argued that memory processes could be influenced by context (Smith et al., 1978). The participants in the present study were in either a truth-telling or lying context for the entirety of the interview. There might have been some differences in how honest people and liars started to encode the interview, questions and answers due to the general context, and the effects of deception on memory might have resulted from the dishonest context. Following comments from a reviewer, we replicated the experiment,[1] in which the participants were not asked to make intentional decisions before the interview; instead, they were allowed to choose whether to lie or be honest for each individual question during the interview, and they did not obtain any benefits for their lies. However, none of the participants lied about any items in the replicated experiment. More work is needed to create a setting that can motivate lies and more closely mimic real life in the future. Second, an item memory test, source memory test and destination memory test were sequentially given 48 h after the interview, and comparisons of performance in the memory tests were conducted to determine the differences between the honest and deception groups. The participants retrieved information about some items in a memory test and were then asked to provide further information in the next memory test. The items presented in the source memory test contained the answers to the item memory test, and the items provided in the destination memory test contained the answers to the source memory test. Therefore, memories of the items contained in a test and/or retrieval-associated memory effects (e.g., retrieval-induced forgetting) could have affected participants' memories of the items in the next test. Although this was the case for both groups, it cannot be ruled out that such a general effect had an influence on the memory tests and potentially influenced the effects of deception on memory. Further experimental investigations may focus on one kind of memory rather than multiple kinds of memory in an experiment, or ask about each item in only one memory test to rule out such influences. Third, it has been suggested that lie-induced arousal will be heightened when the severity of the consequences of lying are increased; thus, attention will be focused on lies, and deception memories will be improved (Cowley & Anthony, 2019). Generally, lying about shopping lists will not have serious consequences. Therefore, the findings observed in the present study need to be generalized with caution. Continued effort is needed to explore whether the effects of deception on memory are a function of the consequences of deception through studies with high ecological validity but without violating research ethics. Moreover, it has been suggested that there are sex differences in lying (DePaulo et al., 1996). Sex differences in deceptive responses and relevant neural responses have also been reported (Gao et al., 2018; Marchewka et al., 2012). However, too few males (only 6) were recruited in the present study. Therefore, our results should be generalized to males cautiously.

In summary, we studied the effects of deception on memory using a daily life paradigm. We found that source memory and destination memory but not item memory were impaired by deception. Individuals who lied many times within a short period of time forgot the exact things about which they had lied about and mistakenly believed that they had lied about many more things than they did. Even worse, they also forgot to whom they lied. Impairments of liars' memories may cause further problems in their lives. Therefore, lying is risky, and one should think over the options before deciding to tell lies.

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Author contributions YL designed the study with the help from ZL. YL collected and ZL analyzed the data. YL wrote the manuscript with the help from ZL and with critical comments from XL.

Data availability Data files, memory tests and R script for data analysis are available from online Figshare repository: https://figshare.com/s/4de6526d8560f82185cd. The experiment was not preregistered.

Declarations

Conflict of interest Yan Li declares that she has no conflict of interest. Zhiwei Liu declares that he has no conflict of interest. Xiping Liu declares that she has no conflict of interest. The authors did not have a

[1] Thirty-two adults (11 males) were recruited in the replicated experiment. They were asked to complete a mock shopping task, a filler task (playing Tetris), and then a baseline memory test. The participants were told that two interviewers would ask them several questions about their shopping lists, and they could answer each question honestly or dishonestly. The participants were paid for 30 yuan for their participation.

financial relationship with any organization for this work. The authors have full control of all primary data.

Ethical approval All procedures performed in the present study involving human participants were in accordance with the Helsinki Declaration and with the ethical standards of the institutional and national research committee.

Informed consent Informed consent was obtained from all individual participants included in the study.

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