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From junior to senior Pinocchio: A cross-sectional lifespan investigation of deception

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ABSTRACT

We present the first study to map deception across the entire lifespan. Specifically, we investigated age-related difference in lying proficiency and lying frequency. A large community sample ($n = 1005$) aged between 6 and 77 were surveyed on their lying frequency, and performed a reaction-time (RT) based deception task to assess their lying proficiency. Consistent with the inverted U-shaped pattern of age-related changes in inhibitory control that we observed in a stop signal task, we found that lying proficiency improved during childhood (in accuracy, not RTs), excelled in young adulthood (in accuracy and RTs), and worsened throughout adulthood (in accuracy and RTs). Likewise, lying frequency increased in childhood, peaked in adolescence, and decreased during adulthood. In sum, we observed important age-related difference in deception that generally fit with the U-shaped pattern of age-related changes observed in inhibitory control. Theoretical and practical implications are discussed from a cognitive view of deception.

1. Introduction

1.1. Executive control and lying

The ubiquity of lies in everyday life does not imply that lying is child's play. Research has shown that lying considerably challenges our cognitive capacities (Vrij & Granhag, 2012; Walczyk, Igou, Dixon, & Tcholakian, 2013). The cognitive load that accompanies lying is, for instance, reflected in slower response times and a higher number of errors, compared to truth telling (i.e., lie effects; e.g., Van Bockstaele et al., 2012; Williams, Bott, Patrick, & Lewis, 2013; but see Suchotzki, Verschuere, Crombez, & De Houwer, 2013). Furthermore, lying evokes more activity in the prefrontal cortex, a brain region that is crucially linked to cognitive or executive control (Abe, 2011; Christ, Van Essen, Watson, Brubaker, & McDermott, 2009; Farah, Hutchinson, Phelps, & Wagner, 2014). Miyake and colleagues distinguished response inhibition, working memory updating, and shifting as the three main executive functions (Miyake et al., 2000), and several lines of research support the involvement of these functions in lying. Evidence has been found for the notion that the truth response is activated first, thereby inducing response conflict and an increased need for response inhibition to prevent the truth from slipping out (Debey, Ridderinkhof, De Houwer, & Verschuere, submitted for publication; Duran, Dale, & McNamara, 2010; Hadar, Makris, & Yarrow, 2012; Vartanian et al., 2013). However, the truth may initially also be kept active in working memory to help the formulation of an alternative, deceptive response (Ambach, Stark, & Vaitl, 2011; Debey, De Houwer, & Verschuere, 2014; Visu-Petra, Miclea, & Visu-Petra, 2012). Finally, shifting may help to flexibly shift between the mental sets associated with truthful and deceptive responses (Visu-Petra, Varga, Miclea, & Visu-Petra, 2013; Visu-Petra et al., 2012).

Apart from a few developmental studies in children (<17 years), deception research has largely neglected that executive control is subject to changes throughout life that may give rise to age-related changes in deception skills. The present study addressed this issue by pursuing a first attempt to depict lying proficiency and lying frequency across the near entire lifespan (targeted age range: 6–82).

1.2. Executive control across life

The relationship between age and executive control ability is best described as an inverted U-curve: Executive control increases across childhood, peaks in late adolescence or young adulthood, and declines thereafter (for reviews, see Craik & Bialystok, 2006; Jurado & Rosselli, 2007; Zelazo, Craik, & Booth, 2004). Several theories have been proposed to explain the cognitive differences at both ends of life. The frontal lobe hypothesis (West, 1996), attributes lifespan differences in

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executive control to specific age-related changes in the frontal lobe, a brain region that is the last to mature and among the first regions to deteriorate during aging (Raz et al., 2005). The global speed hypothesis (Salthouse, 1996), however, states that a general factor — global processing speed — determines the performance levels that can be reached on most cognitive tasks (Bashore & Smulders, 1995). It is therefore imperative to control for global processing speed when examining age-related changes in executive control (e.g., Span, Ridderinkhof, & van der Molen, 2004; Williams, Ponesse, Schachar, Logan, & Tannock, 1999).

1.3. Response inhibition across life

Response inhibition has been proposed to be the executive function that may be at the heart of deception (Spence et al., 2001; Vartanian et al., 2013). We therefore looked more closely into studies that examined age-related differences in inhibitory control. This literature is characterized by three main limitations. First, whereas some studies controlled for processing speed or — more general — baseline performance (e.g., Rush, Barch, & Braver, 2006; Troyer, Leach, & Strauss, 2006; Van der Elst, Van Boxtel, Van Breukelen, & Jolles, 2006; Williams et al., 1999), others did not (Collette, Germain, Hogge, & Van der Linden, 2009; Davidson, Amso, Anderson, & Diamond, 2006; Schroeter, Zysset, Wahl, & von Cramon, 2004). Second, most studies only examined inhibitory control in a restricted age range (e.g., Bub, Masson, & Lalonde, 2006; Bunge, Dudukovic, Thomason, Vaidya, & Gabrieli, 2002), or investigated lifespan changes in a discontinuous manner by reducing the lifespan to a group of children, young adults, and older adults (e.g., Christ, White, Mandernach, & Keys, 2001; van de Laar, van den Wildenberg, van Boxtel, & van der Molen, 2011). Third, as highlighted by Band, van der Molen, and Logan (2003), many studies are underpowered.

A limited number of studies addressed these main limitations. Van der Elst et al. (2006; $n = 1856$; age range: 24–81) and Troyer et al. (2006; $n = 272$; age range: 18–94), administered the Stroop task throughout adulthood. In the Stroop task, participants name the ink color in which color words are presented. Because naming the word is the prepotent response, response inhibition is needed on trials where the ink color is incongruent with the word name (e.g., GREEN in red; MacLeod, 1991). Both studies showed that the Stroop effects (i.e., incongruent minus congruent) in errors and reaction times (RTs) systematically increased with age. Also in an adult sample ($n = 304$; age range: 20–86), Borella, Carretti, and De Beni (2008) administered the Hayling sentence completion test (Burgess & Shallice, 1997), in which participants complete high-closed sentences, either with an expected word (initiation condition) or with a word that is unrelated to the sentence content (inhibition condition). A comparison of both conditions showed that with age, participants had more difficulty to inhibit expected words. Williams et al. (1999) administered a global stop-signal task to 275 participants that were between 6 and 81 years old. The stop-signal task requires participants to perform a visual choice reaction-time task, but to withhold their response on an infrequent number of trials (e.g., 25%) in which a stop signal occurs shortly after presentation of the stimulus (Verbruggen & Logan, 2008). Stop-signal reaction time (SSRT; an estimated time to stop responses) decreased between early childhood and adolescence, and increased again thereafter. However, the loss during adulthood was less pronounced than the gain during childhood. Bedard et al. (2002), examining 317 participants aged 6 to 82, found a more symmetric U-shaped pattern with a modified stop-signal task that required participants to suppress their response in the presence of one signal, but not in the presence of another.

In sum, there is some evidence for an age-related inverted U-course of inhibitory control, yet studies remain restricted in sample size, age range, and efforts to correct for baseline performance.

1.4. Lying ability across life

From the idea that lying depends on executive control, one could infer the hypothesis that deception ability will change with age in a similar vein as the executive functions it relies on. So far, the relationship between age and lying has been primarily examined in studies that focused on the development of lying in the age range between 2 and 16 years. A common used paradigm to assess children's lying ability is the temptation resistance paradigm (Lewis, Stanger, & Sullivan, 1989; Talwar & Lee, 2002). In this paradigm, an experimenter asks children not to peek at or play with a toy when left alone. Because the situation is very tempting, many children transgress the instruction. Upon returning, the experimenter asks whether the child has peeked at or played with the toy. If the child denies transgression, follow-up questions (e.g., "What do you think the toy is?") are asked to assess strategic lying, that is, the ability to make statements that are consistent with the initial lie. Performance on the Stroop task predicts the decision to lie in children between 2 and 8 years, and the sophistication of strategic lies told between 3 and 16 years (Talwar & Lee, 2008).

Of interest with regard to the impact of aging on lying skills is a study of Abe et al. (2009) in which participants with Parkinson's disease and healthy controls were instructed to lie or tell the truth about recognizing certain items. It was found that patients had more difficulty to lie relative to healthy controls. The finding that this poorer performance in patients was correlated with their prefrontal hypometabolism, points to the possibility that the typical deterioration of the frontal lobe in old age may also hamper lying skills.

The observation that executive control ability predicts lying from the very first appearances of lies substantiates the idea that executive control is a core component of lying. It is therefore striking that no research has yet examined lying proficiency across the entire lifespan.

1.5. Lying frequency across life

We also explored how lying frequency evolves over life. Several studies found that people lie on average one to two times a day (DePaulo, Kashy, Kirkenol, Wyer, & Epstein, 1996; Vrij, 2008). Some of these studies reported upon how age impacts on lying frequency. Serota, Levine, and Boster (2010; Study 1) surveyed 1000 U.S. adults (aged 18–65+) how many times they had lied in the past 24 h. Participants lied on average 1.65 a day, and lying frequency decreased with aging. The diary study of DePaulo et al. (1996) also found that young adults lie more often than older adults. Levine and colleagues further found an increased lying frequency in adolescents (aged 14–17; Levine, Serota, Carey, & Messer, 2013) as compared to the lying frequency reported by adults in other studies. It is, however, important to note that Serota et al. (2010) (see also Halevy, Shalvi, & Verschuere, 2014) showed that the mean may provide a biased statistic in lying frequency research: Many people reported not to lie, and a very small proportion of the surveyed samples (i.e., 'prolific liars') appeared responsible for most of the lies.

Although lying frequency has never been systematically investigated under the age of 14, developmental studies have shown that with increasing age, children become more inclined to lie (Chandler, Fritz, & Hala, 1989; Talwar & Lee, 2002; Talwar, Murphy, & Lee, 2007; Wilson, Smith, & Ross, 2003).

2. Current study

Our primary goal was to investigate age-related changes in lying proficiency and lying frequency. We predicted an age-related inverted U-course for both lying proficiency and lying frequency. This prediction was based upon the previously observed age-related inverted U-course for response inhibition capacity. As those studies were restricted in sample size, age range, or efforts to correct for baseline performance, we also sought to replicate the age-related inverted U-course for response inhibition capacity. Finally, we explored whether the effect of age on lying proficiency and lying frequency would be related to changes in response inhibition capacity. This study was run in a science museum, as a convenient means to assess a large sample that has substantial variation in age.

We assessed *inhibitory control* by means of a global stop-signal task that was similar to the one used in the lifespan study of Williams et al. (1999). While participants make speeded classification judgements of two letters (X or O?), this tasks requires one to withhold responding when an auditory stop signal is presented, allowing to estimate the time to stop (SSRT; Verbruggen & Logan, 2008). *Lying proficiency* was measured by means of the Sheffield lie test (Spence et al., 2001) that requires speeded yes/no responses to questions (e.g., "Are you in Africa?"). A color cue on the screen instructs when to lie or tell the truth. This paradigm has been successfully used with children (Otgaar, Verschuere, Meijer, & Van Oorsouw, 2012), adolescents (Verschuere, Spruyt, Meijer, & Otgaar, 2011), and adults (Fullam, McKie, & Dolan, 2009; Kaylor-Hughes et al., 2011). In this task, one typically observes significant lie effects in error rates and RTs, indicating that lying is typically slower and more error-prone than truth telling (Spence et al., 2001; Van Bockstaele et al., 2012). *Lying frequency* was assessed with the Serota self-report measure that asks for number of lies told in the past 24 h. Due to the expected non-normal distribution of lying frequency, we will report mean frequencies, but focus on unbiased statistics (i.e., the median), and examine whether the number of prolific liars changes with age.

3. Method

3.1. Participants

In August 2012, 1005 visitors of Science Center NEMO (Amsterdam, the Netherlands), aged between 6 and 77 years were recruited in the study.[1] From this original sample, outlying participants were removed separately for the stop-signal task, the Sheffield lie test, and the Serota questionnaire (see below for details).

3.2. Apparatus

The stop-signal task and Sheffield lie test were run on Dell latitude E5510 laptops (2.4 GHz Core i3 M730 processor; 15.6-inch color monitor). Closed headphones were used to present the stop signals in the stop-signal task and the questions in the Sheffield lie test. The stop-signal task was programmed and presented using the Tscope library for C/C++ programming (Stevens, Lammertyn, Verbruggen, & Vandierendonck, 2006). Stop-signal functions were adapted from STOP-IT software (Verbruggen, Logan, & Stevens, 2008). The Sheffield lie test was programmed and presented using Inquisit version 1.33 software. Participants sat approximately 40 cm from the screen.

3.3. Questionnaires

A demographic questionnaire assessed gender, date of birth, mother language, and education/profession.

Lying frequency was assessed with the Serota et al. (2010) self-report lying frequency questionnaire. Participants were asked how many times they had lied in the past 24 h. They had to specify the lie rate for five different receivers (family members, friends, work/school-related contacts, acquaintances, and strangers) along two deceptions modes (face-to-face, and other forms of deception [e.g., internet, telephone]). A sum score of the 10 mode-receiver combinations was calculated as an estimate of lying frequency.[2]

3.4. Tasks

3.4.1. Stop-signal task

The stimuli used in the stop-signal task were the uppercase letters "X" and "O" (Courier, 48 pt., bold). They were presented in white in the middle of a black screen. Depending on the response mapping that was counterbalanced across participants, the letter X required a left response ("z" key) on a QWERTY keyboard and the letter O a right response ("/" key), or vice versa. The stimuli remained on the screen for the maximum response time of 2000 ms, followed by a blank screen of 300 ms. On a random selection of 25% of the trials, a stop signal (750 Hz, 75 ms) was presented shortly after the stimulus onset. The stop-signal delay (SSD; the time interval between the presentation of the stimulus and the stop signal) was initially set at 250 ms and continuously adjusted according to a staircase tracking algorithm (Levitt, 1970): The SSD decreased with 50 ms when inhibition was unsuccessful, and increased with 50 ms after successful inhibition. This procedure allows obtaining an approximate .50 probability of stopping.

The task started with two practice phases. The first practice phase (8 trials; 2 stop-signal trials) focused on the go task. Participants were asked to respond to the letters as quickly and accurately as possible. They were told that occasionally they would hear an auditory signal, but were instructed to ignore it in this phase. In the second phase (16 trials; 4 stop-signal trials), the actual stop-signal task was explained. Participants were told that they would have to try to stop their response when they heard the signal. They were also told that sometimes it would be fairly easy to stop their response, whereas other times stopping would be hard. To prevent participants from applying a waiting strategy, it was stressed that the computer would delay the presentation of the stop signal when they started waiting for it. After each practice phase, performance feedback was provided. When necessary, the practice phases could be run again until the participants understood the task. After practicing, participants performed the test phase with 160 trials (i.e., four blocks of 40 trials; 40 stop-signal trials in total). In the middle of the task, a self-paced break was provided. In each block, the letters X and O were presented equally often and followed equally often by a stop signal. The task took approximately 10 min.

3.4.2. Sheffield lie test

Thirty general knowledge questions served as stimuli (see Appendix A). Half of the questions could be truthfully answered with a "yes" response (e.g., "Is grass green?"), whereas the other half required a truthful "no" response (e.g., "Can pigs fly?"; note that we provide the English translation here, whereas the stimuli were presented in Dutch). The questions were matched for length, and tested for understandability in a pilot study. On each trial, a single prerecorded question (always produced by the same male Dutch speaker) was presented through the headphones. At the same time, the "YES" and "NO" response labels were presented on the screen according to the response

[1] This research was part of Science Live, the innovative research program of Science Center NEMO that enables scientists to carry out real, publishable, peer-reviewed research using NEMO visitors as volunteers.

[2] For exploratory reasons, we also assessed subjective lying proficiency and difficulty using 10-point Likert scales: "How good do you think you are at lying?" (*1* = definitely not good, *10* = very good), and "How difficult is lying to you?" (*1* = not at all difficult, *10* = very difficult). Also emotionality of lying was assessed by asking participants how they generally feel when they lie by means of the 9-point Self-Assessment Manniken (SAM; Bradley & Lang, 1994) rating scales for valence (*1* = very sad, *9* = very happy) and arousal (*1* = very calm, *9* = very aroused). With age, lying was rated as being more difficult, more arousing, and more negative. Participants who lied more often rated themselves as relatively good liars, found lying more easy, and experienced less negative and aroused feelings during lying compared to participants who lied less. Interestingly, participants who lied faster in the Sheffield lie test also rated themselves as better liars, found lying less difficult, and/or rated lying less negatively. However, these correlations were small (full results can be obtained on request).

Table 1
Variables of interest from the stop-signal task.

Age (years)	Description	*n*	% female	SSRT *M* (*SD*)	SSD (ms)	p(r|s)	GoRT (ms)	GoAcc (%)
6–8	Early childhood	47	43	299 (105)	536 (170)	.46 (.06)	910 (163)	95.15 (2.89)
9–12	Midchildhood	247	53	257 (86)	500 (215)	.46 (.07)	827 (227)	97.12 (2.58)
13–17	Adolescence	89	54	229 (66)	461 (260)	.45 (.08)	761 (284)	97.23 (2.70)
18–29	Young adulthood	77	69	196 (54)	473 (238)	.46 (.07)	718 (265)	98.86 (1.74)
30–44	Midadulthood	201	68	203 (56)	475 (217)	.45 (.07)	733 (238)	98.78 (1.75)
45–59	Older adulthood	119	50	211 (60)	562 (238)	.43 (.08)	841 (276)	98.68 (1.80)
60–77	Seniors	52	67	215 (66)	578 (229)	.43 (.09)	858 (248)	98.82 (1.33)
6–77	Total	832	58	228 (77)	503 (227)	.45 (.08)	796 (251)	97.91 (2.42)

Note. SSRT = stop-signal reaction time (ms); SSD = stop-signal delay (ms); p(r|s) = proportion of responses given a stop signal; GoRT = reaction time on Go trials (ms); GoAcc = accuracy on Go trials as a percentage of correct Go trials.

mapping (YES = left, NO = right, or vice versa). Both labels were presented in a blue or yellow color, and a color rule (counterbalanced across participants) designated when to lie or tell the truth (blue = lying, yellow = truth telling, or vice versa). From the start of the question, participants had 6 s to give a response, and the RT reflects the time between the onset of the question and the response. When no answer was given within the response deadline, the next question was automatically presented. After a response, or after 6 s without a response, a blank screen of 200 ms was inserted before the next question was presented.Before the start of the task, the experimenter provided the instructions that were also presented on the screen. Participants first completed two practice phases. In the first practice phase, 6 questions (3 yes- and 3 no-questions) that were not used in the test phase were presented twice in a fixed order of increasing difficulty (truth/yes-questions, lie/yes-questions, truth/no-questions, lie/no-questions). In the second practice phase, the same questions were randomly presented. In both practice phases, a picture of an upward thumb, downward thumb, or a clock were presented as feedback to a correct, incorrect, or too late response, respectively. After each practice phase, a performance feedback screen enabled the experimenters to see if the participant understood the task. If necessary, the task was explained again and participants completed the practice phases a second time. The test phase consisted of three blocks of 40 trials, so that each question required twice a truthful response, and twice a deceptive response. Feedback was no longer provided after each trial. The intertrial interval was set at 300 ms. Blocks were separated by a self-paced break. At the end of the task, participants received feedback based on their RT lie effect (i.e., RT_{TRUTH}–RT_{LIE}), classifying them as a good, mediocre, or bad liar. The task lasted approximately 10 min.

4. Procedure

Individuals who did not speak Dutch, who were younger than 6, or older than 82 were not eligible to participate. Volunteers were shortly briefed about the experiment and signed an informed consent. If participants were younger than 18, the informed consent was signed by an accompanying parent. Participants were first asked to fill out the demographic and lying questionnaires. Next, they entered a research room, where they performed the stop-signal task, followed by the Sheffield lie test. Up to four participants could be tested simultaneously. After completing the tasks, an oral and written debriefing was provided. Overall, the experiment took approximately 30 min.

5. Results

Of 11 participants, day of birth were missing and hence their data could not be used in the analyses. To allow for comparisons with previous lifespan studies on the stop-signal task (Bedard et al., 2002; Williams et al., 1999), we divided participants into seven age groups (see Table 1 for a description of the age groups).

For ANOVAs and hierarchical regressions, we calculated Cohen's *f* as an effect size, using the following formula: $f = \sqrt{[\eta^2_p/(1 - \eta^2_p)]}$. According to Cohen (1992), *f*s from 0.10, 0.25, and 0.40 represent small, medium, and large effects, respectively. For *t*-tests, we used Cohen's *d* as an effect size, with *d* values from 0.20, 0.50, and 0.80 representing small, medium, and large effects, respectively (Cohen, 1988). When Levene's test for equal variances was significant, degrees of freedom were adjusted.

In preliminary analyses, we also investigated the impact of gender. However, as gender differences were not our primary focus, these analyses are only briefly described in Footnote 3.

5.1. Stop-signal task

5.1.1. Data analysis

Because it takes a number of trials for the tracking algorithm to adjust the SSD to the point where participants can successfully inhibit their responses on approximately 50% of the stop-signal trials, we discarded the first presentation block from the analyses. The SSRT was estimated using the integration method (Logan, 1981; Verbruggen, Chambers, & Logan, 2013). We removed RTs below 200 ms (1.40%) and trials with RT recording errors (0.02%). Too late responses (1.34%) were set at the maximum response time of 2000 ms. Spearman–Brown split-half reliability (i.e., odd vs. even) was high for RT on go trials (i.e., GoRT; $\rho = .99$), and low for SSRT ($\rho = .45$). The low reliability of SSRT may be attributed to a slowing strategy that some participants developed during the task, despite clear instructions not to do so. Indeed, a repeated measures ANOVA on GoRT revealed a main effect of Block, $F(2, 1662) = 92.06$, $p < .001$, $f = 0.33$, showing a gradual increase of GoRT across blocks (*p*s < .001 in follow-up *t*-tests). This slowing strategy may also explain why the proportion of responding given a stop signal (p[r|s]) was overall rather low (see Table 1). The finding that p(r|s) reached .50 in another study in which participants completed the same task (Suchotzki, Crombez, Debey, van Oorsouw, & Verschuere, 2014), supports the notion that not task parameters, but strategy use accounts for our results. By means of simulations, Verbruggen et al. (2013) showed that in case of strategic slowing in the stop-signal task, reliable and unbiased SSRTs can be obtained by estimating the SSRT for smaller blocks using the integration method and then taking the average across blocks. Accordingly, our estimation

[3] To examine potential gender differences in the stop-signal task, we performed univariate ANOVAs on GoRT and SSRT with Age (7 age groups) and Sex (Male vs. Female) as predictors. In the GoRT analysis, the main effect of Sex proved significant, $F(1, 818) = 4.29$, $p = .04$, $f = 0.07$, indicating that male participants were slower to respond ($M = 829$ ms, $SD = 268$) than female participants ($M = 772$ ms, $SD = 235$). No effects of Sex were found for SSRT, *F*s < 1.
For the Sheffield lie test, we performed repeated measures ANOVAs on error rates and mean RTs with Deception (Truth vs. Lie), Age, and Sex as predictors. In the error analysis, no effects of Sex were found, *F*s < 1. The RT analysis yielded a main effect of Sex, $F(1, 859) = 10.92$, $p < .01$, $f = 0.11$, indicating that female participants ($M = 3421$ ms, $SD = 359$) were overall slower to respond than male participants ($M = 3366$ ms, $SD = 336$).

of the SSRT equals the average of the SSRTs calculated for each of the three presentation blocks using the integration method.

We removed the data of three participants who did not (entirely) complete the stop-signal task. Hundred forty participants were defined as outlying and excluded from the analyses because they met at least one of the following lenient outlier criteria proposed by Congdon et al. (2012): (1) a p(r|s) less than .25 or greater than .75, (2) no response on more than 40% of the go trials, (3) more than 10% errors on go trials, and (4) an SSRT that was negative or smaller than 50 ms. From the remaining sample, we additionally discarded 16 participants whose SSRT was 2.5 standard deviations (*SD*s) removed from the mean SSRT of the age group they belonged to. Table 1 displays the remaining sample across the age groups. Following Williams et al. (1999), we not only analyzed SSRT, but also GoRT as a measure of global speed processing.

5.1.2. Response execution (GoRT)

A one-way ANOVA on GoRT with Age (7 age groups) as predictor revealed a main effect of Age, $F(6, 825) = 7.33$, $p < .001$, $f = 0.23$. To further examine the effect of age on GoRT, we conducted a hierarchical polynomial regression on GoRT, where we subsequently entered the linear, quadric, and cubic functions of Age as predictors (see Table 2, Analysis A). The quadratic function of Age proved to be a significant predictor of GoRT. In line with this quadratic term, visual inspection of Fig. 1 (and Table 1) shows that GoRT decreased during childhood and gradually increased again during the course of adulthood. Planned comparisons of subsequent age groups revealed significant decreases between early childhood and adolescence, $ts \geq 1.99$, $ps < .05$, $0.27 \geq ds \leq 0.38$. Further, older adults were significantly slower than middle-aged adults, $t(219.93) = 3.54$, $p < .001$, $d = 0.43$. All other comparisons were non-significant, $ts \leq 1$.

5.1.3. Response inhibition (SSRT)

A one-way ANOVA on SSRT with Age as predictor yielded a main effect of Age $F(6, 825) = 22.95$, $p < .001$, $f = 0.41$. The relationship between SSRT and age was further examined in a hierarchical polynomial regression on SSRT (see Table 2, Analysis B). To control for baseline speed, we entered GoRT as a predictor in a first step (Williams et al., 1999; see also McAuley, Yap, Christ, & White, 2006; Rush et al., 2006, for similar control procedures in other inhibition tasks). In subsequent steps, the linear, quadratic, and cubic functions of Age were entered as predictors. GoRT was no significant predictor of SSRT. In contrast, the linear and quadratic functions of Age were found to significantly contribute to SSRT. Fig. 1 and Table 1 show that the SSRT decreased from early childhood to young adulthood and thereafter increased again, albeit much more shallowly. Planned comparisons between subsequent age groups revealed significant decreases in SSRT between early childhood and young adulthood, $ts \geq 2.58$, $ps \leq .01$, $0.35 \geq ds \leq 0.54$. In contrast, the SSRT of subsequent age groups in adulthood did not differ from each other, $ts < 1$. A post-hoc comparison between young adults and seniors showed only a trend toward an increase in SSRT, $t(127) = 1.80$, $p = .07$, $d = 0.32$. Moreover, the SSRT in early childhood was significantly larger than the SSRT of seniors, $t(75.68) = 4.72$, $p < .001$, $d = 0.97$.

Table 2
Hierarchical regression analyses predicting global processing speed (GoRT) and response inhibition capacity (SSRT) by (the linear, quadric, and cubic functions of) age.

Analysis and step	Cumulative *RR*	*F* for *R*	ΔR^2	ΔF	*p* for ΔF	β	*t* for β
A. GoRT							
Age	.056	2.61	.003	2.61	.11	−0.06	1.61
Age^2	.210	19.21	.041	35.71	<.001	1.10	5.98
Age^3	.211	12.81	.000	0.05	.82	−0.15	0.23
B. SSRT							
GoRT	.037	1.12	.001	1.12	.29	0.04	1.06
Age	.315	45.77	.098	90.30	<.001	−0.31	9.50
Age^2	.374	44.83	.040	38.78	<.001	1.11	6.23
Age^3	.374	33.72	.000	0.48	.49	−0.45	0.69

Note. Age = linear function of Age; Age^2 = quadratic function of Age; Age^3 = cubic function of Age.

5.2. Sheffield lie test

5.2.1. Data analysis

Trials with latencies below 300 ms (0.94% of the original data set), and trials without a response within the 6 s deadline (0.80%) were discarded. For RT analyses, we excluded trials with errors (10.58%), and truth and lie trials with RTs that were 2.5 *SD*s removed from each individual's mean RT on truth and lie trials (1.59%).

Fourteen participants did not perform the Sheffield lie test, because they quit the experiment during or after the stop-signal task. In an outlier analysis at participant level, we sequentially removed (1) two participants whose mother language was not Dutch and who clearly stated that they did not understand certain words in the task, (2) 28 participants who had an error rate that was 2.5 *SD*s higher than the mean error rate of the age group they belonged to, (3) 71 participants who had less than 60% truth and lie trials left for the RT analyses after the RT outlier analysis, and (4) six participants who had an overall RT that was 2.5 *SD*s away from the mean RT of the age group they belonged to. Table 3 shows the distribution of the remaining sample across the age groups. Based on this sample, Spearman–Brown split-half reliability (i.e., odd vs. even) was found to be acceptable ($\rho = .68$) for the RT lie effect (see Table 3 for reliability coefficients per age group).

We first performed an overall analysis to examine potential effects of age on lying proficiency. Mean error rates and RTs were subjected to repeated measures ANOVAs with Deception (Lie vs. Truth) as within-subjects variable, and Age (7 age groups) as between-subjects variable. Irrespective of the presence or absence of Age by Deception interactions revealing age-related variations in lie effects, we aimed to draw a more accurate picture of the relationship between age and lying by examining lying performance after accounting for the age-related variance explained by truth telling (i.e., baseline) performance. We applied a similar control procedure as applied in the SSRT analysis: For both errors and RTs, we fitted a hierarchical polynomial regression on the lie value (e.g., RT on lie trials), in which we first controlled for baseline performance by entering the truth value (e.g., RT on truth trials) as a predictor, followed by the linear, quadratic, and cubic functions of Age in the subsequent steps. We compared lying performance between age groups using the estimated lie values after having partialled out the variance attributable to truth telling performance. Each estimated lie value was calculated by (1) computing the predicted lie value based on a model that included the truth value as the only predictor for the observed lie value (e.g., RT lying $= \beta_0 + \beta_1$. RT truth telling), and (2) subtracting this predicted lie value from the observed lie value.

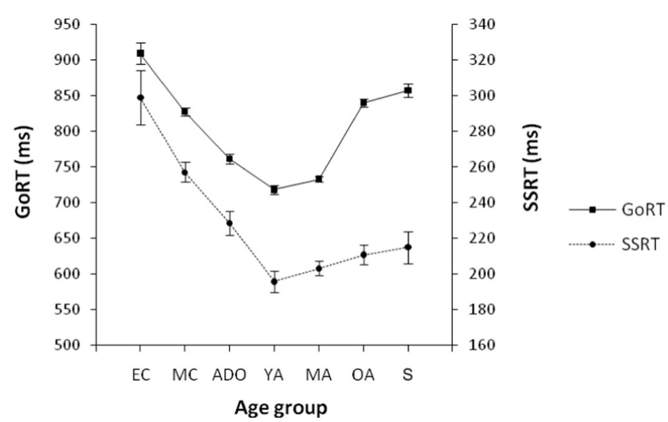

Fig. 1. GoRT and SSRT. EC = Early childhood; MC = Midchildhood; ADO = Adolescence; YA = Young adulthood; MA = Midadulthood; OA = Older adulthood; S = Seniors (see also Figs. 2–3).

Table 3
Error rates and mean reaction times in the Sheffield lie test.

Age group	n	% female	Error rate (%)				Reaction times (ms)			
			Truth M (SD)	Lie M (SD)	Lie effect M (SD)	Estimated lie M (SD)	Truth M (SD)	Lie M (SD)	Lie effect M (SD)	Spearman–Brown's ρ of RT lie effect
Early childhood	62	45	15.00 (8.50)	20.20 (9.41)	5.20 (7.78)	1.91 (7.40)	3703 (354)	3838 (381)	135 (186)	.38
Midchildhood	252	54	11.60 (7.49)	16.86 (8.61)	5.26 (7.28)	1.32 (6.95)	3331 (333)	3463 (365)	133 (186)	.51
Adolescence	95	53	10.82 (6.81)	14.59 (8.12)	3.78 (5.87)	−0.31 (5.77)	3163 (293)	3301 (321)	138 (143)	.52
Young adulthood	79	66	5.97 (5.00)	8.55 (6.23)	2.58 (5.36)	−2.43 (5.18)	3100 (313)	3246 (398)	146 (181)	.68
Midadulthood	205	68	4.96 (3.97)	9.03 (6.52)	4.07 (5.54)	−1.14 (5.53)	3229 (260)	3507 (329)	278 (207)	.72
Older adulthood	129	49	5.77 (5.06)	10.40 (6.90)	4.63 (6.20)	−0.42 (6.02)	3277 (281)	3584 (350)	307 (219)	.74
Seniors	51	69	6.63 (5.74)	12.65 (6.82)	6.03 (7.11)	1.14 (6.68)	3527 (365)	3859 (394)	332 (203)	.73
Total	873	58	8.53 (7.00)	13.06 (8.52)	4.53 (6.50)	0.00 (6.36)	3298 (340)	3504 (391)	206 (208)	.68

5.2.2. Errors

The ANOVA revealed a main effect of Deception, $F(1, 866) = 315.54$, $p < .001$, $f = 0.60$, indicating the presence of an error lie effect, with more errors made on lie trials than on truth trials (see Table 3). The main effect of Age, $F(6, 866) = 49.41$, $p < .001$, $f = 0.59$, pointed to age-related changes in the overall error rate. However, these main effects were subsumed under a significant Deception by Age interaction, $F(6, 866) = 2.69$, $p = .01$, $f = 0.14$, suggesting that the error lie effect differed among age groups. Planned comparisons revealed that the error lie effect was significantly different from zero in all age groups, $ts \geq 4.28$, $ps < .001$, $0.48 \geq ds \leq 0.85$. Visual inspection of the age-related error lie effects (see Fig. 2 and Table 3) shows a decrease between midchildhood and young adulthood, and an increase thereafter. Comparing subsequent age groups disclosed a trend toward a smaller error lie effect in adolescence than midchildhood, $t(345) = 1.78$, $p = .08$, $d = 0.21$. Further, the error lie effect in young adulthood was significantly smaller compared to all other age groups, $ts \geq 2.05$, $ps \leq .04$, $0.27 \geq ds \leq 0.56$, except for adolescence, $t(172) = 1.39$, $p = .17$. The error lie effects did not differ between the youngest children and the seniors, $t < 1$.

The hierarchical regression analysis revealed that the error rate on truth trials explained a significant proportion of variance in the lie error rate (see Table 4, Analysis A). After accounting for this baseline effect, both the linear and quadratic function of Age were also found to be significant predictors of the lie error rate. The estimated lie error rates after controlling for truth telling performance (Fig. 2 and Table 3) showed a similar age-related U-pattern as observed for the error lie effects. Planned comparisons between subsequent age groups exposed significant decreases between midchildhood and young adulthood, $ts \geq 2.04$, $ps \leq .04$, $0.25 \geq ds \leq 0.38$. Further, there was a trend toward an increase between young- and midadulthood, $t(287) = 1.80$, $p = .07$, $d = 0.24$ (other $ts \leq 1.52$). However, seniors had a significantly larger lie error rate than young adults, $t(87.83) = 3.24$, $p < .01$, $d = 0.61$. The lie error rate of seniors did not differ from that of the youngest children, $t < 1$.

5.2.3. Reaction times

The ANOVA produced a main effect of Deception, $F(1, 866) = 767.05$, $p < .001$, $f = 0.94$, indicating the presence of an RT lie effect with slower responses on lie trials than on truth trials (see Table 3). The main effect of Age, $F(6, 866) = 32.83$, $p < .001$, $f = 0.48$, signified that overall speed varied among age groups. These main effects were subsumed under a significant Deception by Age interaction, $F(6, 866) = 24.98$, $p < .001$, $f = 0.42$, suggesting that the RT lie effect differed between age groups. Planned comparisons showed that the RT lie effect was significant in all age groups, $ts \geq 5.37$, $ps < .001$, $0.71 \geq ds \leq 1.64$. The RT lie effect followed an age-related S-shaped curve with an evident increase between young- and midadulthood (see Fig. 3 and Table 3). Comparisons of subsequent age groups revealed that only this increase reached significance, $t(282) = 4.99$, $p < .001$, $d = 0.66$ (other $ts \leq 1.19$). Additional comparisons disclosed no significant changes in the RT lie effect between early childhood and young adulthood, $ts < 1$. There was a small trend toward a larger RT lie effect in seniors than midadulthood, $t(254) = 1.66$, $p = .10$, $d = 0.26$.

The hierarchical regression analysis showed that after controlling for the significant contribution of RT on truth trials, all functions of Age explained a significant proportion of variance in RT on lie trials (see Table 4, Analysis B). Fig. 3 and Table 3 display the estimated lie RTs after accounting for truth telling performance, and confirm the age-related S-shaped curve found for RT lie effects. Planned comparisons of subsequent age groups demonstrated again that only the manifest lie RT increase between young and middle-aged adults reached significance, $t(282) = 5.10$, $p < .001$, $d = 0.68$ (other $ts \leq 1.24$). Post-hoc comparisons further confirmed that there were no significant RT increases between early childhood and young adulthood,

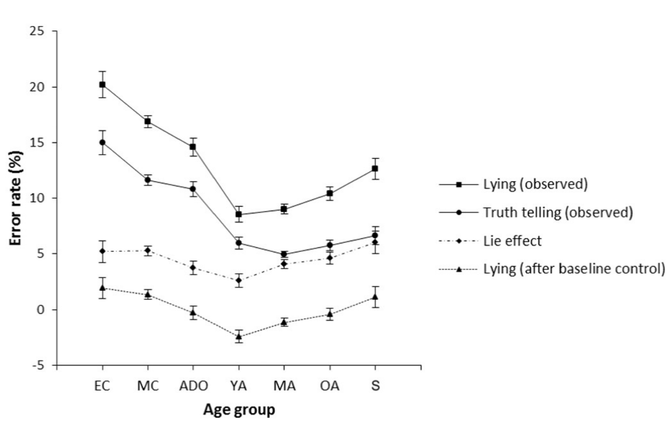

Fig. 2. Observed error rates for truth telling and lying, error lie effects, and estimated error rates for lying after baseline control.

Table 4
Hierarchical regression analyses predicting lying proficiency (lying values for errors and RTs) by (the linear, quadric, and cubic functions of) age.

Analysis and step	Cumulative RR	F for R	ΔR^2	ΔF	p for ΔF	β	t for β
A. Errors lying (%)							
Errors truth telling	.665	689.12	.442	689.12	<.001	0.67	26.25
Age	.672	357.36	.009	14.74	<.001	−0.11	3.84
Age^2	.682	252.39	.015	23.75	<.001	0.66	4.87
Age^3	.683	190.03	.001	2.04	.154	0.69	1.43
B. Mean RT lying (ms)							
Mean RT truth telling	.847	2212.70	.718	2212.70	<.001	0.85	47.04
Age	.868	1328.82	.036	126.39	<.001	0.19	11.24
Age^2	.869	890.85	.001	4.43	.036	0.21	2.10
Age^3	.870	674.82	.002	7.31	.007	−0.88	2.70

Note. Age = linear function of Age; Age^2 = quadratic function of Age; Age^3 = cubic function of Age.

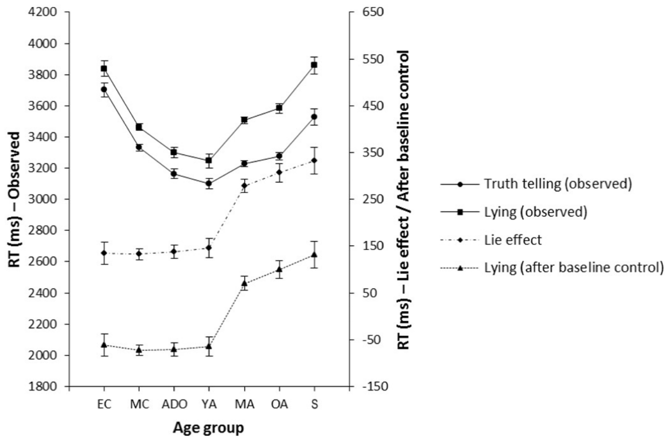

Fig. 3. Observed mean RTs for truth telling and lying, RT lie effects, and estimated mean RTs for lying after baseline control.

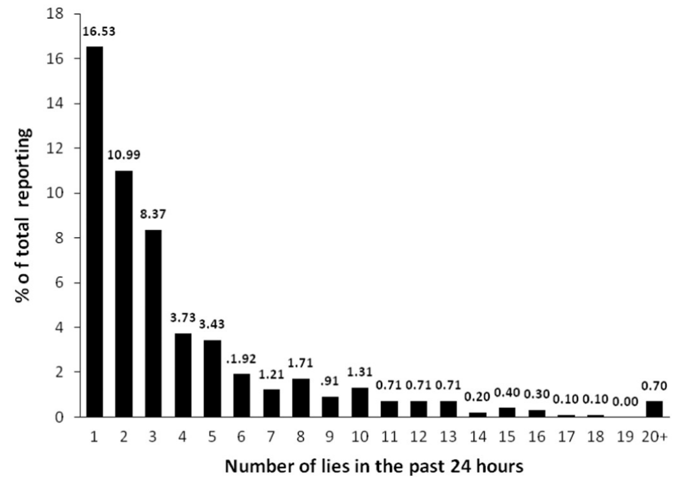

Fig. 4. Lying frequency.

ts < 1. The RT increase between midadulthood and seniors was marginally significant, $t(254) = 1.89$, $p = .06$, $d = 0.30$.

5.3. Lying frequency

Data from one participant (a 12-year old boy) were removed because he reported an implausible lying frequency of 315. One additional participant was excluded as data were missing from his Serota questionnaire. Table 5 displays the remaining sample. As effect sizes for the Mood's median tests, we calculated Cramér's *V*, for which values from .10, .30, and .50 respectively reflect small, medium, and large effects (Cramér, 1999).

Table 5 shows that on average participants told about two lies a day, whereas the median frequency was one lie a day. A Mood's median test with Age as predictor showed that the median lying frequency differed among age groups, $\chi^2(6, N = 992) = 24.41$, $p < .001$, $V = .06$. Based on the absolute values, one could detect an increase of lying frequency during childhood with a peak in adolescence, followed by a decrease during adulthood. Planned comparisons showed that median lying frequency was higher in midchildhood than in early childhood, $\chi^2(1, N = 397) = 6.31$, $p = .01$, $V = .13$. Adolescents lied significantly more than any other age group, $7.84 \geq \chi^2\text{s} \leq 18.91$, $p \leq .01$, $.14 \geq V \leq .31$, except for a trendwise difference with young adulthood, $\chi^2(1, N = 184) = 3.21$, $p = .07$, $V = .13$. The difference in median frequency between young adulthood and seniors failed to reach significance, $\chi^2(1, N = 144) = 1.31$, $p = .25$. Further, median lying frequency was not different for early childhood and seniors, $\chi^2(1, N = 163) = 1.02$, $p = .31$.

When examining the distribution of lies based on the entire sample, we found that nearly half of the participants reported not to have lied in the past 24 h (see Table 5). The proportion of individuals who reported to have lied decreased as a function of the number of lies, so that 50.67% of the lies was told by 8.87% prolific liars (see Fig. 4). This non-normal distribution was present in all age groups (see Table 5). Though a Chi-square test showed that the proportion of prolific liars did not differ across age groups, χ^2 $(6, N = 992) = 8.14$, $p = .23$, the age-related pattern was by and large similar to the reversed U-course found in the median analysis, with a peak number of prolific liars in adolescence.

5.4. Correlational analysis

We produced a correlation matrix to examine the relationship between measures of the stop-signal task, Sheffield lie test, and lying frequency (see Table 6). SSRT was incorporated from the stop-signal task. From the Sheffield lie test, we included the estimated lie error rate and estimated lie RT after accounting for the variance explained by truth telling performance. Because lying frequency was not normally distributed, we used Spearman's rho (ρ) as correlation coefficient.

Evidence for a relation between executive (inhibitory) control and lying proficiency was weak. Participants who had longer SSRTs tended to have higher estimated lie error rates, but faster estimated lie RTs in the Sheffield lie test. However, given that values of .10, .30, and .50 respectively reflect small, medium, and large correlations, the observed correlations were very small. Although the analysis showed that individuals who reported a higher number of lies also lied faster in the Sheffield lie test, that correlation can also be considered small. Moreover, stop-signal task performance was not related to lying frequency.

6. Discussion

How does lying evolve over life? This was the primary question we aimed to address in the current study. In a large sample aged 6–77, we measured accuracy and speed of lying in the Sheffield lie test as measure of lying proficiency. The number of lies told in the past 24 h provided a measure of lying frequency. Based on previous studies that

Table 5
Descriptives of self-reported lying frequency.

Age group	*n*	% female	Lying frequency *M* (*SD*)	Lying frequency *Mdn*	% no lies	% 1–5 lies	% > 5 lies
Early childhood	102	53	1.75 (4.82)	0	63.73	29.41	6.86
Midchildhood	295	54	2.59 (4.92)	1	42.71	43.39	13.90
Adolescence	101	53	2.80 (3.08)	2	25.74	59.41	14.85
Young adulthood	83	67	1.94 (2.62)	1	37.35	51.81	10.84
Midadulthood	216	67	2.06 (5.22)	1	49.07	43.06	7.87
Older adulthood	134	49	1.82 (3.16)	0	50.75	38.81	10.45
Seniors	61	69	1.57 (2.47)	0	55.74	34.43	9.84
Total	992	58	2.19 (4.34)	1	45.97	43.04	10.99

Note. Age = linear function of Age; Age^2 = quadratic function of Age; Age^3 = cubic function of Age.

Table 6
Correlations between variables of interest.

	1	2	3
1. SSRT	–	–	–
2. Error % lying	.08*	–	–
3. RT lying	−.09*	.02	–
4. Lying frequency	−.01	−.03	−.10**

Note. Error % lying and RT lying represent the estimated values after baseline control.
* $p < .05$.
** $p < .01$.

highlighted the role of inhibitory control in lying (Christ et al., 2009), and the finding that inhibitory control typically follows an inverted U-curve with age (Jurado & Rosselli, 2007), we expected that lying proficiency and lying frequency would follow an age-related U-curve. Because studies examining age-related difference in inhibitory control were restricted in sample size, age range, or efforts to correct for baseline performance, we also sought to replicate the age-related U-curve shape in response inhibition capacity in a Stop-signal task.

6.1. Response inhibition capacity across life

Concentrating first on the stop-signal task, we found that the SSRT decreased from early childhood to young adulthood. The SSRT increased again thereafter, though this decline in inhibitory control only followed a trend. This pattern aligns with the results found in the lifespan stop-signal task study of Williams et al. (1999), with two exceptions: (1) in contrast with the study of Williams et al., GoRT did not significantly explain variance in SSRT, and (2) SSRT peaked in young adulthood, whereas it already peaked in adolescence in Williams' study. Our study largely replicates the findings of Williams et al. in a larger sample, and adds to the few lifespan studies that investigated the maturation and decline of inhibitory control after controlling for general processing speed. The presence of age-related differences in response inhibition (SSRT) after accounting for the variance attributable to response execution (GoRT), together with the larger age-related trends for response execution relative to response inhibition, coincide with the findings of Williams and others (Bedard et al., 2002; Ridderinkhof, Band, & Logan, 1999), and contrast with the hypothesis that only global differences in speed would underlie age-related differences in executive control (Salthouse, 1996). The relatively weaker age-related trends for response inhibition compared to response execution may suggest that withholding planned actions is relatively stable across life due to an early development and long preservation, or may reflect the possibility that individual differences play a larger role than age differences (Bedard et al., 2002). The observation that age affected inhibition more heavily in childhood than in adulthood supports the notion that aging is not merely development in reverse (Craik & Bialystok, 2006; Sander, Lindenberger, & Werkle-Bergner, 2012).

6.2. Lying proficiency across life

The most basic finding that emerged from the analysis of the Sheffield lie task that assessed lying proficiency is the observation that the error and RT lie effects as previously observed in student populations were significantly different from zero in all age groups. As such, our study forms strong support for the cognitive view of deception, as it shows that the notion of lying being more cognitively demanding than truth telling applies to the entire lifespan. However, analyzing lying performance after controlling for truth telling performance showed that age groups differed in the way they can cope with these cognitive demands. The instances of erroneously telling the truth on lie trials followed the expected age-related U-shaped pattern: The lie error rate decreased with age during childhood, was lowest in young adulthood, and thereafter increased at a relatively slower pace, so that error-proneness did not differ between the youngest children and the seniors. In contrast, the RT data revealed an unforeseen age-related S-shaped pattern, with RT lie effects that did not significantly change from young childhood until young adulthood. The most plausible explanation seems to relate to the reliability of the RT lie effect. As can be seen in Table 3, the split-half reliability of the RT lie effect is the lowest in young childhood and systematically increases with age. The relatively low reliability in childhood reflects a low consistency in speed of responding, which may have masked their true (larger) RT lie effect. That children had a low response consistency may suggest that the Sheffield lie test was generally too difficult for them. Another, not mutually exclusive explanation may be that children were too distracted during the Sheffield lie test. We often observed that children were able to focus well during the stop-signal task, but that attention continuously dropped when they had to perform the subsequent Sheffield lie test. Having to perform this second cognitively demanding task, while knowing that more entertaining attractions were yet to be explored in the science center, may have lowered their motivation to perform well. Based on this motivational explanation, one could also argue that a speed-accuracy trade-off may have further contributed to the small lie effect in children. Although children were still overall slower than young adults, one cannot entire rule out the possibility that their motivation to quickly finish the task may have encouraged children to weigh speed over accuracy. Such a speed-accuracy trade-off may even have occurred apart from motivation, as a few studies have shown that children often tend to apply a decision rule that is optimized for speed (Carp, Fitzgerald, Taylor, & Weissman, 2012; Nardini, Bedford, & Mareschal, 2010). Future studies are thus needed to test our research question again in a context that allows more consistent responding within children, for example, by making the task less difficult (e.g., blocking truth and lie trials would reduce the need for task switching), and/or by letting them perform the task in more controlled, less distractible lab setting, and/or by rewarding them to equally weigh speed and accuracy.The age-related U-curve of lying accuracy and the decline of lying speed during adulthood, are in line with the notion that lying requires executive control. The lack of strong correlations between stop-signal task and Sheffield lie test performance seems to tone down such an interpretation, as it casts doubt on the hypothesis that response inhibition is one of the executive functions at the heart of lying. Yet, a closer look at the literature on response inhibition suggests that our findings do not necessarily contradict the response inhibition hypothesis of lying. Previous studies that found a correlation between deception ability and inhibitory control in adult samples used the Stroop task to assess inhibitory control (e.g., Visu-Petra et al., 2012). Developmental studies that examined the relation between executive control and lying administered several inhibition tasks, but only found a significant correlation with the Stroop task (Evans, Xu, & Lee, 2011; Talwar & Lee, 2008). One explanation may be the cognitively and neurally multifaceted character of response inhibition (Wager et al., 2005). Different response inhibition paradigms may tap into different subcomponents of response inhibition that recruit partially distinct regions of the neural inhibition network (Aron, 2011; Eagle, Bari, & Robbins, 2008; Jahfari et al., 2011; Nigg, 2000; Sebastian et al., 2013; Swick, Ashley, & Turken, 2011). The Stroop task and Simon task, for example, would tap into ‘interference inhibition’, as they involve the inhibition of unintentionally activated response tendencies. The Go/No-go task, on the other hand, where a prepotent response tendency has to be inhibited on a minority of trials, would engage the ‘action withholding’ component. Finally, in the stop-signal task, ‘action cancelation’ would be needed to inhibit responses that have already been initiated (Sebastian et al., 2013). When coupling these insights to our study, the lack of a strong association between the deception task and the stop-signal task may be explained by their reliance on different inhibitory subcomponents. Whereas the stop-signal measures action withholding, lying in our Sheffield lie test may have tapped more strongly into the component of interference inhibition as conflict would arise between the truthful and deceptive response dimension. However, it is possible that with questions that are less trivial and elicit more dominant truth responses, interference inhibition may be preceded by action withholding or cancelation. Future (lifespan) studies that allow a more elaborate investigation may test the above-mentioned explanation by a more extensive assessment of the inhibition network.

6.3. Lying frequency across life

We also aimed to draw a lifespan picture of lying frequency. Three main findings resulted from the Serota questionnaire that assessed participants' lying frequency in the past 24 h. First, the mean lying frequencies of two lies on average per day reported in adulthood were in line with the typical finding that adults tell one to two lies a day (DePaulo et al., 1996; Serota et al., 2010). Second, the unbiased measure (i.e., median) showed that lying frequency increased during childhood, peaked in adolescent years, and then decreased into old age to the point that seniors lied equally often as the youngest children. Third, in each age group, lies were non-normally distributed around the mean: (1) Many participants did not lie, and (2) the distributions of lies were positively skewed, so that most lies were told by a small group of prolific liars. With these results, we replicated and extended prior findings (Halevy et al., 2014; Levine et al., 2013; Serota et al., 2010).

The finding that the age-related changes in lying frequency were by and large similar to the age-related changes in lying proficiency and SSRT seems to support the idea that better lying proficiency due to better executive skills may boost the frequency to lie. However, the correlational analysis did not favor such an account: Whereas lying proficiency only modestly predicted lying frequency, stop-signal task performance proved no significant predictor. It seems plausible that the small variety in lying frequency due to the non-normal distribution made it difficult to find strong relationships. Irrespective of this explanation, the lack of a relationship with stop-signal task performance may be explained by the fact that lying would rely on a different inhibitory subcomponent than measured in the stop-signal task (cf. supra).

It is crucial to realize that some developmental studies have shown that next to executive control (and closely related: theory of mind understanding), lying behavior can also be influenced by one's moral evaluation of lies (Jensen, Arnett, Feldman, & Cauffman, 2004; Talwar & Lee, 2008; Xu, Bao, Fu, Talwar, & Lee, 2010). Future research that assesses lying frequency would therefore do well by questioning participants about the type of lies told, and how they morally evaluate and justify these lies. The increase of lies told in childhood may, for instance, reflect a surge of prosocial, other-oriented lies as a result of an increasing positive evaluation of prosocial lies (Heyman, Sweet, & Lee, 2009; Popliger, Talwar, & Crossman, 2011; Xu et al., 2010). The peak lying frequency of adolescents may reflect a large number of lies told to gain autonomy from their parents (Jensen et al., 2004; Perkins & Turiel, 2007). Finally, the decrease of lying frequency throughout adulthood would be consistent with the finding that older adults become more focused on positive emotional experiences in social situations and therefore become more sensitive to moral information (Carstensen, Fung, & Charles, 2003; Narvaez, Radvansky, Lynchard, & Copeland, 2011).

6.4. Limitations

Several limitations of the current study can be recognized. First, shortening the tasks may have sacrificed reliability. Second, the Sheffield lie test examines lying in a restricted and artificial design, because (1) it only focuses on lying to yes/no questions, (2) it precludes the emotional involvement of lying that may characterize lying in real life, and (3) participants are instructed to lie. Such a design rules out the role of theory of mind understanding (i.e., lying in real life requires the understanding that a false belief can be instilled in others) and moral reasoning that have been linked to lying ability (e.g., Talwar & Lee, 2008). However, we do think this restricted design was adequate to address our research question, because it allowed measuring more purely the executive control aspects involved in a basic form of lying. The use of such a basic form of lying may, however, explain why the explained variance of age-related terms was relatively smaller than the variance explained by baseline performance. Third, we could not examine the impact of education on lying proficiency, because education levels were not assessed for all participants. One could expect that the average education level in our study was similar to those in the studies that were also run in science musea (Williams et al., 1999; Bedard et al., 2002). In these studies, the majority of participants had high education levels. Such a sample restriction to higher educated individuals may have prevented more pronounced U-curves in our study, as it has been shown that the age-related cognitive decline is more pronounced in people with a low level of education (Coffey, Saxton, Ratcliff, Bryan, & Lucke, 1999; Van der Elst et al., 2006). Fourth, our research was limited to only one executive function, response inhibition capacity, and should be extended with assessment of other executive functions (i.e., working memory updating and shifting). Fifth, one could argue that the cross-sectional design may have distorted our results because people with different ages were born and raised in a different time period (Schaie, 2013). However, recent findings suggest that longitudinal designs may be more misleading with regard to cognitive changes than cross-sectional designs (Salthouse, 2014). Whereas cross-sectional studies mostly find age-related U-curves in cognitive abilities, longitudinal studies often observe that performance levels are maintained or even increase with aging (Salthouse, 2009; Schaie, 2013). This suggests that experience with a test on a previous assessment may influence performance on a following assessment. In line with this idea, some quasi-longitudinal studies tested the same birth cohort for the first time in different years, and obtained patterns that best resemble those observed in cross-sectional studies (Kaufman, 2013; Salthouse, 2014). Consequently, we think our findings cannot be ascribed to the specific research method we used.

6.5. Implications for research and practice

Our study points to an important implication for deception research. Deception studies often use convenient samples of undergraduate participants. However, because our research shows that young adults are overall the best liars, the true impact of the mentally taxing aspect of lying (e.g., the role of executive control) and the effectiveness of cognition-based deception techniques, may be underestimated. Our findings should therefore stimulate deception researchers to attach more attention to the role of age by testing their hypotheses in a larger age range.

Future research will tell whether the observed age-related pattern of lying proficiency holds in other lie tests and in more realistic settings. If our findings are generalizable, then also practitioners would gain from taking into account the age of suspects. Our findings suggest that whereas the lies of older suspects would be relatively easy to catch, young adults would be more successful in getting away with their lies. Given that crimes are mostly committed by adolescents and young adults (Loeber & Farrington, 2014), our findings concur with the plea to use strategies to increase cognitive load to be able to detect deception (Walczyk et al., 2013), perhaps particularly so in young adults for whom lie detection may be a more difficult task.

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Appendix A. Questions used in the Sheffield lie test.

Questions requiring a truthful "yes" response	Questions requiring a truthful "no" response
Is water wet?	Is water dry?
Is ice cold?	Is ice warm?
Can birds fly?	Can pigs fly?
Is a crocodile an animal?	Is a computer an animal?
Is Amsterdam in the Netherlands?	Is Amsterdam in Switzerland?
Are giants big?	Are giants small?
Do cars have four wheels?	Do cars have six wheels?
Is an igloo made of ice?	Is an igloo made of stone?
Is sausage meat?	Is salad meat?
Is stone hard?	Is stone soft?
Is fire warm?	Is fire wet?
Is milk white?	Is milk green?
Are bananas yellow?	Are bananas red?
Is grass green?	Is grass blue?
Does a butcher sell meat?	Does a butcher sell bread?

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