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ORIGINAL PAPER

Trust and Deception in Children with Autism Spectrum Disorders: A Social Learning Perspective

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Abstract Previous research has demonstrated abnormal trust and deception behaviors in children with Autism Spectrum Disorders (ASD), and we aimed to examine whether these abnormalities were primarily due to their specific deficits in social learning. We tested 42 high-functioning children with ASD and 38 age- and ability-matched typically developing (TD) children in trust and deception tasks and a novel condition with reduced social components. Results indicated that while TD children improved their performance with more social components, children with ASD lacked this additional performance gain, though they performed similarly as TD children in the condition with reduced social components. Our findings highlight that deficits of ASD in trust and deception are primarily associated with failure of use of social cues.

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Introduction

Humans can benefit from social information during social interaction, such as eye gazes and facial cues, to learn social standards (e.g., Bushwick 2001; Hareli et al. 2015), rules (e.g., Jones et al. 2013; Wang et al. 2015), and language (e.g., Baldwin 1993; Dominey and Dodane 2004; Tomasello and Farrar 1986; Yu and Ballard 2007). Social learning is a cumulative and cyclic process, which begins almost at birth and takes several years of training and practice (Bushwick 2001). However, individuals with autism spectrum disorder (ASD), who have limited attention to and understanding of social cues, may be less likely to benefit from social learning. This impairment has been proposed to contribute to core symptoms of ASD, such as defective social communication (Bushwick 2001). In the current study, we investigated two kinds of social behaviors, trust and deception, under the framework of social learning.

Trust and deception are two types of social behaviors that children learn as they grow up. Preschoolers develop selective trust to determine whether others are trustworthy based on their past reliability, motives, and past deceiving behaviors (e.g., Corriveau and Harris 2009; Koenig and Harris 2005; Vanderbilt et al. 2011). Children with ASD, however, tend to show a trust bias towards other people's testimony, and unconditionally give credence to information provided by them (Yi et al. 2013, 2014). They also experience difficulty using facial cues to selectively trust others (Ewing et al. 2015). Closely related to trust behaviors, deception, a milestone of children's social cognitive development, also experiences

remarkable development in the preschool years. As children grow up, they deceive others more frequently with more sophisticated strategies (Chandler et al. 1989; Russell et al. 1991; Sodian et al. 1991). However, children with ASD tend to have difficulties with lying, deceiving, and manipulating beliefs of other people (Baron-Cohen 1992; Li et al. 2011; Russell et al. 1991; Sodian and Frith 1992; Talwar et al. 2012; Yirmiya et al. 1996).

Typically, children's trust and deception performance was assessed in the context of social learning, where children need to rely on social cues provided by another person (Yi et al. 2014). Yi et al. (2014) found that children with ASD display slower learning rates than TD children regarding how to distrust and deceive an adult after being repeatedly deceived. Given the complexity of the tasks, it remains an open question whether these learning impairments primarily stem from deficits in general learning abilities as opposed to social learning per se. The present study aimed to examine whether similar learning impairments persist with reduced social components when cueing information is provided by physical markers as opposed to by a human actor. We compared the trust and deception behaviors between ASD and TD groups in a social cue condition, adopted from tasks in Yi et al. (2014), as well as in a non-social cue condition in which children had to rely on physical cues. In the social cue condition, children had to find a hidden prize, with an informant always providing misleading information about its location; then they switched the roles: the informant tried to find the prize and children were given a chance to help or misguide her. The non-social cue condition followed a similar procedure as the social cue condition except that the informant, an actual human in the social cue condition, was replaced with a physical marker in the non-social cue condition. Compared to the social cue condition, all the executive steps are still present in this non-social cue condition: children need to learn whether the cueing information is false, inhibit impulsiveness to follow the false information, and suppress the action to indicate the truth. However, they do not need to rely on social cues provided by another person (e.g., verbal instructions and gestural information), which requires understanding others' intention to distrust and manipulate others' mental states to deceive. Thus, if children with ASD have relatively intact general learning, they should have similar performance as TD children in the non-social cue condition. On the other hand, based on their specific deficit in social learning, we would expect a group difference in the social cue condition. On the contrary, if they were impaired in general learning, they should display poorer performance in comparison to TD children in both conditions.

Method

Participants

Forty-two Chinese children with ASD (age range 4.31–8.22 years, $M = 5.95$, $SD = 0.84$) and 38 age- and ability-matched Chinese TD children (age range 4.00–7.00 years, $M = 5.73$, $SD = 0.71$) were recruited for this study. This age range was chosen based on the previous study (Yi et al. 2014) and our pilot results, to ensure that most children, especially children with ASD, could understand the task instructions and complete the task. To determine the minimum sample size required in the current study, we have conducted a prior power analysis based on effect sizes discovered in a previous study with similar paradigms (Yi et al. 2014). Our sample size was adequate for obtaining a power over 0.9. None of the participants had participated in our previous studies or relative research projects.

Children in the ASD group were recruited from a special school for ASD, while children in the TD group were recruited from a normal primary school in China to participate in the study. All children with ASD included in our study were previously diagnosed by two experienced pediatric clinicians strictly according to the diagnostic criteria for ASD in the DSM-IV-TR (American Psychiatric Association 2000). Since the Autism Diagnostic Observation Schedule (ADOS; Lord et al. 2000) and the Autism Diagnostic Interview-Revised (ADI-R; Lord et al. 1994) have not been officially validated and widely used in China, we confirmed the diagnosis of children with ASD using the Chinese version of Autism Spectrum Quotient: Children's version (AQ-Child[1]), the Social Responsive Scale (SRS[2]), and the Social Communication Questionnaire (SCQ[3]). All questionnaires were scored based on the parents' reports.

Children with ASD were recruited first and randomly assigned to either the social cue or the non-social cue condition. TD children were then recruited to match the ASD group by their (a) chronological age, (b) non-verbal IQ, measured by Combined Raven Test (CRT-C2), and (c) verbal ability, measured by Peabody Vocabulary Test-Revised (PPVT-R) (see Table 1). TD children were then also randomly assigned to the social cue or the non-social cue condition.

[1] The AQ was translated by R.W.S. Chan, W.S. Liu, K.K. Chung, C.S. Sheh & E.K.F. Woo (2008), Hong Kong Working Group on ASD, cprc@hkusua.hku.hk.

[2] The SRS is the Chinese version translated from the Constantino and Gruber (2002) version.

[3] The SCQ is the Chinese version translated from Rutter et al. (2003) Copyright© 2003 by Western Psychological Services (Fourth Printing, April 2012).

Table 1 Sample sizes, age, CRT scores, and PPVT scores of the four groups of participants

Group	Social cue condition		Non-social cue condition	
	TD	ASD	TD	ASD
N (female)	17 (5)	22 (4)	21 (6)	20 (1)
Age range	4.00–7.00	4.62–7.62	4.15–6.96	4.31–8.22
Mean age	5.72 (0.69)	6.09 (0.76)	5.73 (0.75)	5.78 (0.91)
CRT (raw scores)	25.41 (8.85)	27.27 (9.01)	25.24 (5.77)	25.95 (9.65)
CRT (standardized scores)	100.69 (13.51)	100.59 (16.25)	100.00 (9.25)	100.69 (18.22)
PPVT	81.29 (11.21)	74.14 (12.35)	83.33 (14.50)	74.55 (15.29)
VMA[a]	6.29 (0.59)	6.05 (0.65)	6.48 (0.60)	6.00 (0.80)

[a] *VMA* verbal mental age, standardized scores calculated from PPVT scores

Procedure

Distrust and Deception Tasks

A 2 (participant group) * 2 (condition) between-subject design was adopted for the experiment. We asked children to randomly participate in either the social cue or the non-social cue condition, instead of completing both conditions, considering the potential carry-over effect, practice effect, and order effect. Each child completed the distrust and the deception tasks sequentially.

The child, Experimenter 1 (E1), and Experimenter 2 (E2) each sat at one side of a table where three identical boxes were placed along a line. The child was asked to participate in a hide-and-seek game to win prizes with the experimenters, and was encouraged to find "as many prizes as possible." The experimenters were trained sufficiently beforehand on performing the tasks: they were asked not to show any expressions while they interacted with children. We used the same experimenters throughout the whole experiment to minimize the potential impact of different experimenters on children's behavior. The whole procedure was illustrated by the schematic drawing in Fig. 1.

Social Cue Condition

In the distrust task, E1 showed three identical boxes and explained the rules to the child: (a) E1 hid a prize in one of the three boxes and the child had to guess where it was; (b) E2 then examined all the boxes and showed the child where the prize was by pointing at one box; (c) the child could keep the prize if he successfully found it, otherwise E2 would keep it.

After confirming that the child understood the rules, E1 announced that the game began: (a) both the child and E2 turned their backs to the table, then E1 kept one box empty, and placed a prize in each of the other two boxes; (b) the child and E2 faced the table again, then E2 examined all the boxes, pointed at the only empty box, and said to the child "the prize is here"; (c) E1 asked the child to pick one box for the prize; (d) E1 opened the box chosen by the child and provided the feedback (i.e., whether or not the child received the prize for his behavior on each trial) accordingly; (e) if the child did not choose the empty box, E1 gave him the prize; otherwise, E1 took a prize out of either one of the two remaining boxes and gave it to E2. The task was repeated for ten times. Finding the prize in five consecutive trials was considered successfully passing the task. Then the session stopped, and the remaining trials were marked as correct.

Following the distrust task, the child proceeded with the deception task, in which the child and E2 essentially exchanged their roles. First, E1 explained the new rules of the deception task to the child: (a) the child should hide a prize in one box for E2 to look for; (b) E2 could keep the prize if she was correct; otherwise, the child could keep it; (c) before taking a guess, E2 asked the child about the location of the prize, and the child should respond by pointing at one box. After confirming that the child understood the rules, E1 announced that the game began: (a) E2 turned her back to the table, and the child hid a prize in one box; (b) E2 turned around to face the table and asked the child about the whereabouts of the prize, and the child responded; (c) E2 "guessed" that the prize was hidden in the box that was just pointed to by the child; (d) E1 opened the pointed box and provided feedback (i.e., whether or not the child received the prize for his behavior on each trial) accordingly; (e) the child received the prize if he pointed at an empty box; if the child pointed at the box with prize, E2 received the prize. Similar to the distrust task, the procedure was repeated for ten times. Children were considered as passing the task if they obtained the prize in five consecutive trials.

Non-social Cue Condition

In the non-social cue condition, we attempted to reduce social components of the distrust and deception tasks. Children no longer played a zero-sum game against E2. Instead, in the distrust task, they tried to win the prize by guessing

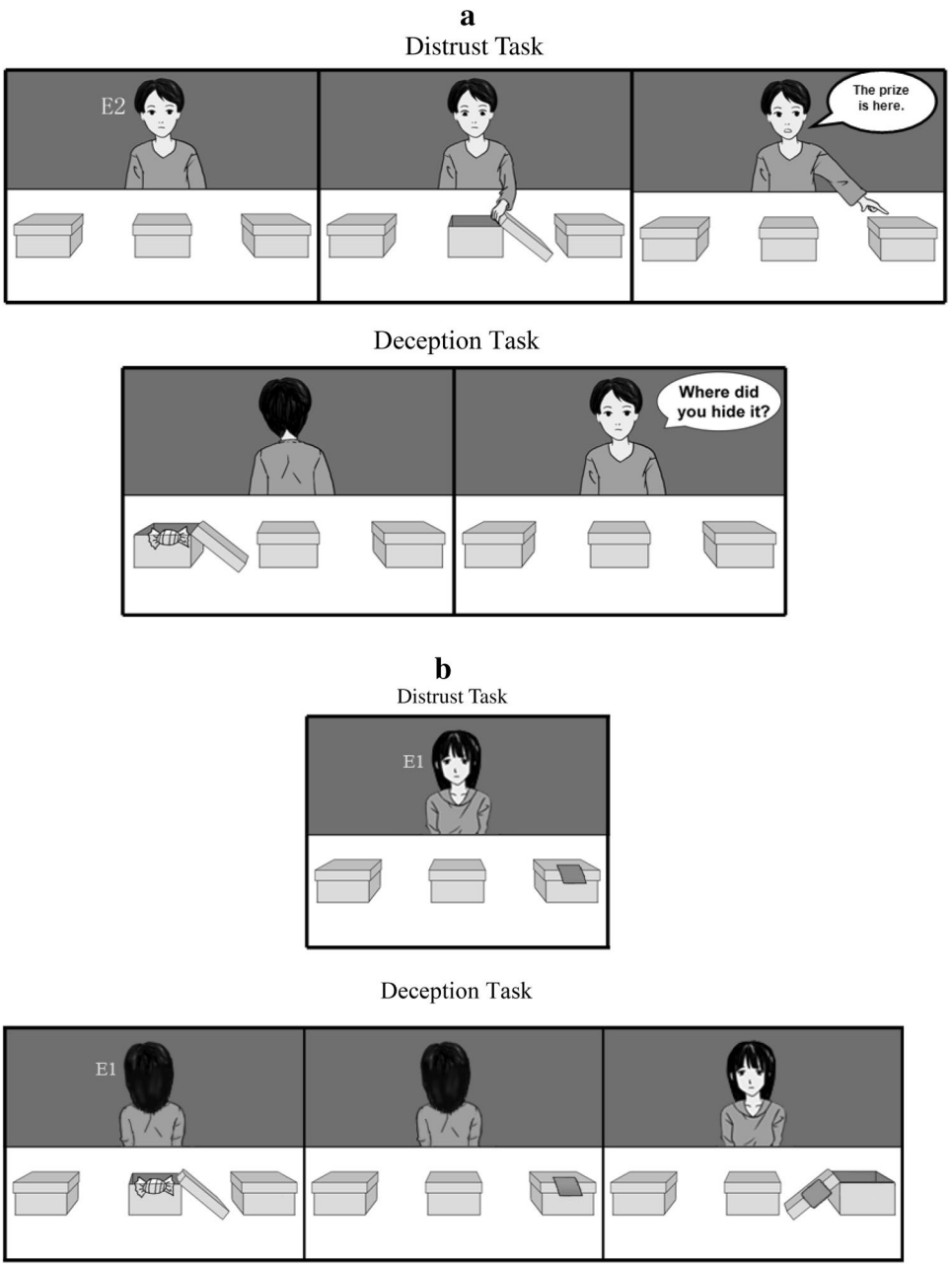

Fig. 1 Schematic drawing of the experimental procedures of the distrust and the deception tasks in the social cue (**a**) and the non-social cue (**b**) conditions

the location of the prize according to a removable sticker attached to one of the three boxes; in the deception tasks, they tried to win the prize by attaching a sticker to an empty box. Since E2 did not participate in the non-social cue condition, the child and E1 sat opposite to each other at a table.

In the distrust task, E1 showed three identical boxes to the child and explained the rules to him: there was a prize in one of the three boxes and the child had to guess where the prize was; he could keep the prize if he guessed right.

The remaining procedures were similar to those of the social cue condition, except that: (a) when the child turned his back to the table, E1 kept one box empty and placed a sticker on it, and placed a prize in each of the other two boxes; (b) right after the child faced the table again, E1 asked him to pick one box for the prize; (c) if the child chose the unbaited box, E1 gave him the prize; otherwise, if the child chose the baited box, E1 took a prize out of either one of the remaining boxes, put it aside, and stated that the prize belonged to neither the child nor E1.

Following the distrust task, the child proceeded with the deception task. E1 explained the new rules to the child: (a) the child should hide a prize in one box and then attach a sticker to one box; (b) the child could keep

Table 2 The average score over ten trials of the social cue and non-social cue conditions in the distrust and deception tasks

Task	Condition	TD	ASD
Distrust	Social cue	9.12 (0.70)	6.32 (2.32)
	Non-social cue	7.90 (1.37)	7.75 (1.65)
Deception	Social cue	9.71 (0.47)	6.95 (3.54)
	Non-social cue	9.00 (1.45)	6.85 (3.36)

the prize if he placed the sticker correctly; otherwise, neither the child nor E1 could keep the prize.

The remaining procedures were similar to those of the social cue condition, except for the following steps: (a) when E1 turned her back to the table, the child hid a prize and placed a sticker to one of the boxes; (b) E1 never asked the child about the whereabouts of the prize; (c) if the child placed the sticker on a box without the prize, he could keep the prize; otherwise, E1 put the prize aside and stated that it belonged to neither the child nor E1.

For the distrust task, if the child chose the box pointed by E2 or baited with a sticker, the trial was scored as 0; otherwise, it was scored as 1. For the deception task, if the child pointed or put a sticker on the box in which he hid the prize, the trial was scored as 0; otherwise, it was scored as 1. Hence, task performance was indicated by an array of 0 and 1 scores.

Data Analysis

We first averaged the task performance across ten trials and conducted ANCOVAs to compare these average scores between groups and conditions, with IQ and PPVT scores as the covariates. We used ANCOVAs since children's IQ and PPVT were correlated with overall trust and deception performance.[4] In our design, children "learned" from the feedbacks whether they received the prize on a trial-by-trial basis. To characterize their learning process, we also compared the two groups with two types of trial-by-trial analyses. One is to compare the two groups regarding the percentage of children who won the prize at each trial. The statistical test appropriate for this type of data is Fisher's Exact test. The other is the survival analysis that quantifies the percentage of children who eventually passed the task (i.e., winning the prize in five successive trials) and the speed of the learning process (i.e., how many trials needed to pass the task). Log-rank tests were used for group comparisons of the learning speed. Finally, we tested the correlations between the trust and deception performance (averaged scores) and their social ability in children with ASD.

[4] Specifically, the overall distrust performance was correlated with the IQ and PPVT scores, p's < 0.05; the overall deception performance was correlated with the PPVT score, $p < 0.01$.

Results

Distrust Task

Overall Performance

An ANCOVA was performed on the average scores of the distrust task (see Table 2) with experimental condition and participant group being independent variables, and IQ and PPVT scores being covariates. Results showed a significant main effect of the participant group: children with ASD were more likely to choose the baited box than TD children in the distrust tasks, $F(1,74) = 14.58$, $p < 0.001$. The main effect of the experimental condition was not significant, $F(1,74) = 0.14$, $p = 0.71$. However, the interaction between the participant group and the experimental condition was significant, $F(1,74) = 14.73$, $p < 0.001$. The simple main effect analysis indicated that in the social cue condition children with ASD were more likely to choose the baited box than TD children, $F(1,74) = 28.51$, $p < 0.001$, but there was no significant difference between the two groups in the non-social cue condition, $F(1,74) = 0.02$, $p = 0.88$.

Trial-by-trial Analysis

Trial-by-trial analyses were performed based on each group's performance in each trial (Fig. 2). The binary distribution (score 1 or 0) for each trial was compared between groups. In the social cue condition, participants in both groups performed similarly in the first trial, $p = 0.22$ (Fisher's Exact test, two-tailed), but TD children outperformed children with ASD on the second trial, $p = 0.01$ (Fisher's Exact test, two-tailed), and in most of the following trials. In the non-social cue condition, the two groups of children had similar performance in all trials, p's > 0.05. So, such a group difference in learning to distrust disappeared in the non-social cue condition when the social components of the tasks were reduced.

Survival Analysis

We conducted a survival analysis to examine how children's trust performance would be affected by feedback over the ten trials. The curves in Fig. 3 represent the percentages of children who failed to distrust E2 at specific time points, and the shaded areas represent 95% confidence intervals. Results of the log-rank tests revealed a group difference of the learning curves in the social cue condition:

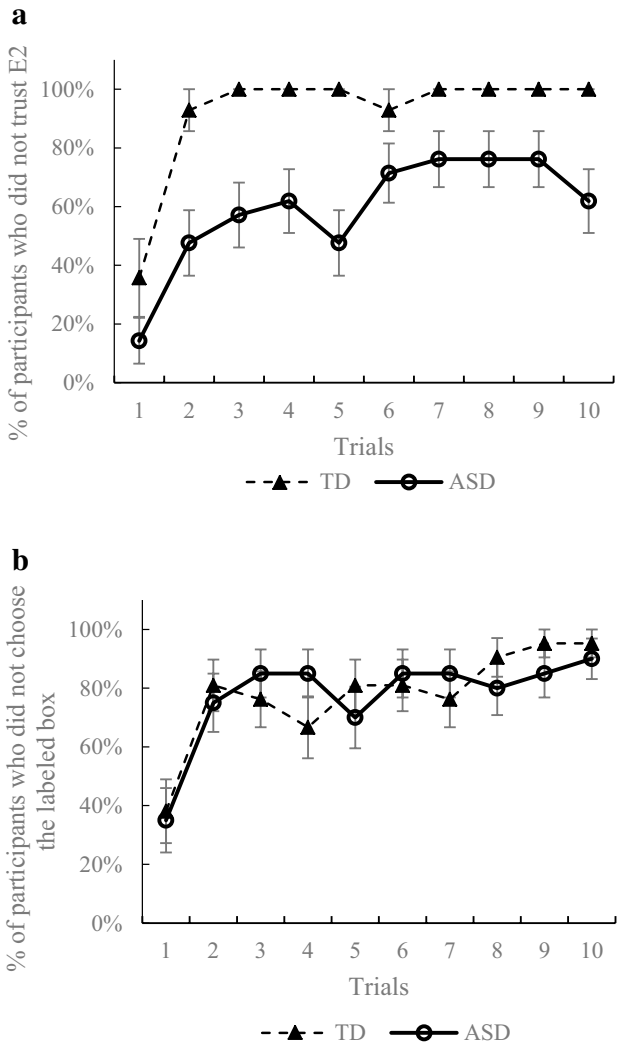

Fig. 2 Percentage of children with ASD and TD children who successfully found the prize as a function of trial numbers in the social cue (**a**) and the non-social cue (**b**) conditions of the distrust tasks. *Error bars* represent 95% confidence intervals

TD children learned faster than children with ASD in the social cue condition, $\chi^2(1)=14.3$, $p<0.001$. More specifically, the learning curve of the TD group showed a steep downward trend: on average 85.71% TD children began to choose the unbaited box in the first two trials, and 92.86% TD children successfully learned to choose the unbaited box at the end of the game. The ASD group had a less steep learning curve than the TD group, and only 47.62% children with ASD successfully learned to choose the unbaited box by the end of the game. In contrast, this group difference disappeared in the non-social cue condition: the two groups had similar learning rates, $\chi^2(1)=0.2$, $p=0.687$. At the end of the game, 51.74% TD children and 65% children with ASD successfully learned to find the prize. Assessing the difference between the conditions for each group separately, we found that TD children learned faster in the social cue condition than in the non-social cue condition, $\chi^2(1)=9$, $p=0.003$, while children with ASD had similar learning rates in both conditions, $\chi^2(1)=1.5$, $p=0.213$.

Deception task

Overall Performance

An ANCOVA was performed on the average scores of ten trials (see Table 2) of the deception task, with the experimental condition and the participant group as independent variables and IQ and PPVT scores as covariates. Results showed a significant main effect of the participant group: children with ASD were less likely to point to the empty box than TD children in the deception tasks, $F(1,74)=12.97$, $p<0.001$. The main effect of the condition, $F(1,74)=0.53$, $p=0.47$, and the interaction between the group and the condition were not significant, $F(1,74)=0.37$, $p=0.54$.

Trial-by-trial Analysis

Similar to the distrust task, a trial-by-trial analysis was performed to test the group difference in the performance of the deception task for each trial. As shown in Fig. 4, in the social cue condition, the TD group performed significantly or marginally better than the ASD group in most of the trials. In the non-social cue condition, the TD group outperformed the ASD group in the first trial, $p<0.001$ (Fisher's Exact test, two-tailed), and 90% TD children placed the sticker on the empty box in the first trial. However, only 35% children with ASD succeeded in the first trial. The group difference attenuated in the following trials and disappeared in the last three trials, p's >0.30 (Fisher's Exact test, two-tailed), as children with ASD learned quickly from the trial-by-trial feedback. In the social-cue deception condition, 71% TD children pointed to the empty box in the first trial, marginally more than the ASD group (38%), $p=0.086$ (Fisher's Exact test, two-tailed).

Survival Analysis

The proportions of participants who failed to learn the strategy at the end of each trial were computed for each group and each condition. As illustrated in Fig. 5, the survival analysis showed a similar trend as in the distrust task: in the social cue condition, 92.86% TD children learned to point to the empty box in the first two trials, while only 66.67% children with ASD learned at the end of the ten trials. In the non-social cue condition, when the social components of the tasks were reduced, 80.95% TD children and 66% children with ASD learned to point to the empty

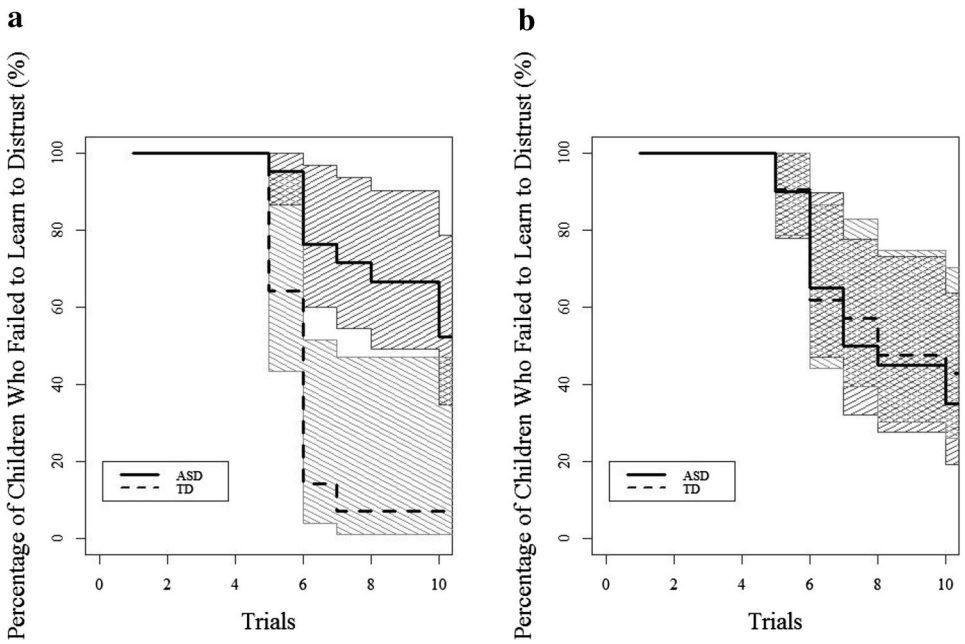

Fig. 3 Survival analyses. Percentages of children who failed to learn to choose the labeled box over trials in the social cue (**a**) and the non-social cue (**b**) conditions of the distrust tasks. The *shaded areas* represent the 95% confidence intervals

box at the end of the game. Log-rank tests showed that TD children learned faster than children with ASD in the social cue condition, $\chi^2(1) = 13.4$, $p < 0.001$, but the two groups had similar learning rates in the non-social cue condition, $\chi^2(1) = 2.4$, $p = 0.12$. When comparing the conditions within each group by the log-rank tests, we found that TD children learned faster in the social cue condition than in the non-social cue condition, $\chi^2(1) = 3.9$, $p = 0.049$, while children with ASD had similar learning rates in both conditions, $\chi^2(1) = 0$, $p = 0.97$.

Correlational Analyses

We also conducted correlational analyses to examine the possible associations between average scores of the distrust and deception tasks and the AQ, SRS, and SCQ scores in the ASD group. We did not find any significant correlation between the AQ, SRS, and SCQ scores and the trust and deception performance in ASD, p's > 0.05.

Discussion

The current study examines whether trust and deception behaviors in children with ASD are primarily affected by specific deficits in learning based on social cues. We recruited children with ASD and TD children aged from 4- to 8-years old, who had never been involved in our previous studies or any relevant research projects. Results of our social cue condition confirm the findings of Yi et al. (2014) regarding the atypical trust and deception behaviors in children with ASD: they were less likely and slower to learn to distrust and deceive the informant who repeatedly deceived them than TD children. Our novel findings came from the non-social cue condition when the social components of the distrust and deception tasks were controlled to reduce their impact: we observed a comparable learning ability in children with ASD relative to TD children. In other words, children with ASD had no difficulty learning these behaviors when the social cues were replaced by physical cues. These findings support the proposition that the abnormality of the trust and deception behaviors in children with ASD was mainly due to their defective learning in the social context (Bushwick 2001).

An alternative explanation of the specific difficulty in ASD children is that the social cue condition is cognitively more demanding simply because more information is available for processing. Compared to physical cues, the human actor brought in verbal instructions and gestural information in the tasks. This is a possible explanation for our results. The two tasks involve qualitatively similar cognitive processes, including general learning that cues are misleading based on trial-by-trial reward feedback, ignoring or inhibiting these cues, deciding to choose the alternative box and so on. The core difference is different ways to deliver the misleading information by using different cues (a person vs. a sticker). Interestingly, we found that TD children learned faster in the social cue conditions than in the non-social cue conditions despite extra available information. Thus, the presence of social cues facilitates rule understanding and problem solving in TD children, who are highly sensitive to social information. We speculate that this social strength or preference in TD children may facilitate their learning in the social context. In contrast,

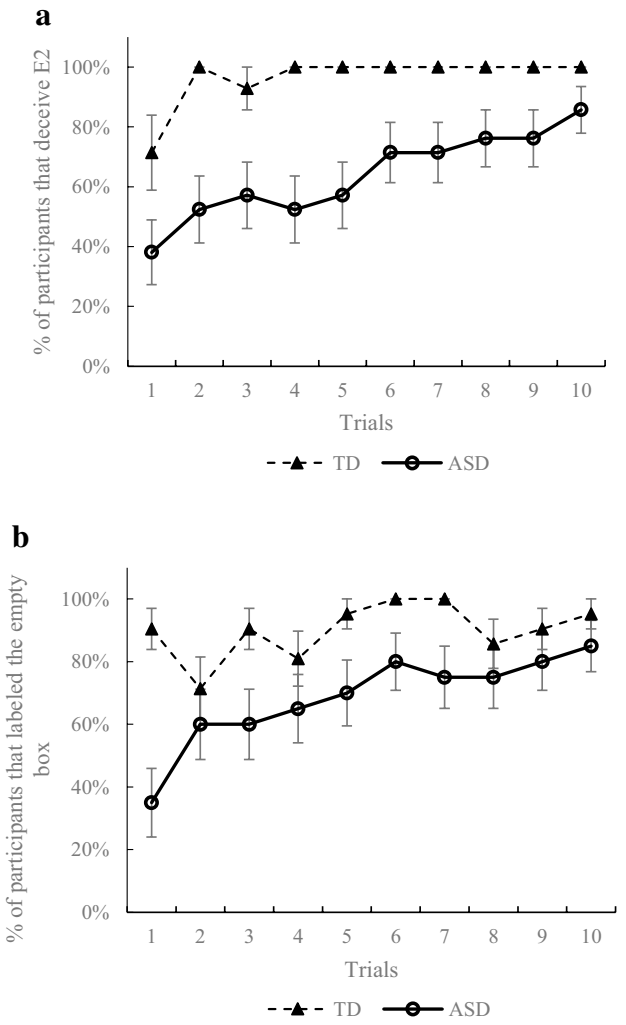

Fig. 4 Percentage of children with ASD and TD children who deceived E2 or labeled the empty box as a function of trial numbers in the social cue (**a**) and the non-social cue (**b**) conditions. *Error bars* represent 95% confidence intervals

children with ASD performed similarly in the social cue and the non-social cue conditions. Thus, the fact that they did not perform *worse* in the social cue condition suggests that extra cueing information (e.g., verbal instruction and gestural information) do not hamper the learning process. It is more likely that social strength or preference, manifested in the behaviors of TD children, is absent in children with ASD due to their diminished awareness and sensitivity to social cues. Future studies are warranted to test this hypothesis directly.

Another alternative way to explain our results of the non-social cue condition is that the two groups may interpret the non-social cues in different ways. Although there was no E2 in the non-social cue condition to interact with the child, the presence of E1 may make the TD child attribute social meanings to the physical marker as it was put by a person. At the same time, it is possible that children with ASD are less likely, compared to TD children, to attribute social meanings to physical cues in the non-social cue condition. In other words, children with ASD may interpret the physical cues in a mechanical way, while TD children may interpret it in a more social way. However, with behavioral paradigms we could not reverse engineer the exact strategies the two groups of participants used. Future research using brain imaging measures such as functional near-infrared spectroscopy (fNIRS) to explore the underlying mechanism of the tasks is therefore recommended.

Besides the findings above, we also discovered a carry-over effect for TD children in the deception task from the previous distrust task. As shown in Fig. 4, TD children in the deception task started with the better performance thus their learning curve was flatter than the distrust task. The carry-over effect by itself is an interesting observation. It might indicate some sort of learning generalization elicited by the previous distrust session, suggesting that social learning of TD children is flexible and generalizable to different conditions. However, such a generalization was not found in children with ASD in the same task, which confirms previous findings that the learning of children with ASD was less flexible and more constrained to specific circumstances relative to TD children (Yi et al. 2014).

Several limitations of the current study should be considered when interpreting our findings. First, limited by the characteristics of our tasks, the social components were not completely removed in our non-social cue condition. As discussed above, children may interpret physical markers in a social way. Despite this concern, removing the role of E2 has remarkably reduced the group differences in both distrust and deception tasks. This result suggests, in the social cue condition, that direct interaction with a person (E2) can cause significant difficulty for ASD to learn distrust and deception behaviors. Second, the cognitive load and complexity of these two conditions are not exactly the same. For example, in the social-cue condition E2 examined the boxes before the child made her judgment, while in the nonsocial cue condition this extra cue was absent. Future studies could introduce a mechanical device to attach the sticker before the child in order to make the available cues better matched between conditions. Third, we did not find any association between the trust and deception performance and the autism scales (AQ, SRS, and SCQ) in children with ASD. Future studies could use more specific social measures (e.g., pragmatic language, Theory of Mind) to explore a possible association between trust and deception and social abilities. Fourth, it is also noteworthy that our sample of ASD children is high-functioning, with an average IQ of approximately 100, which limits

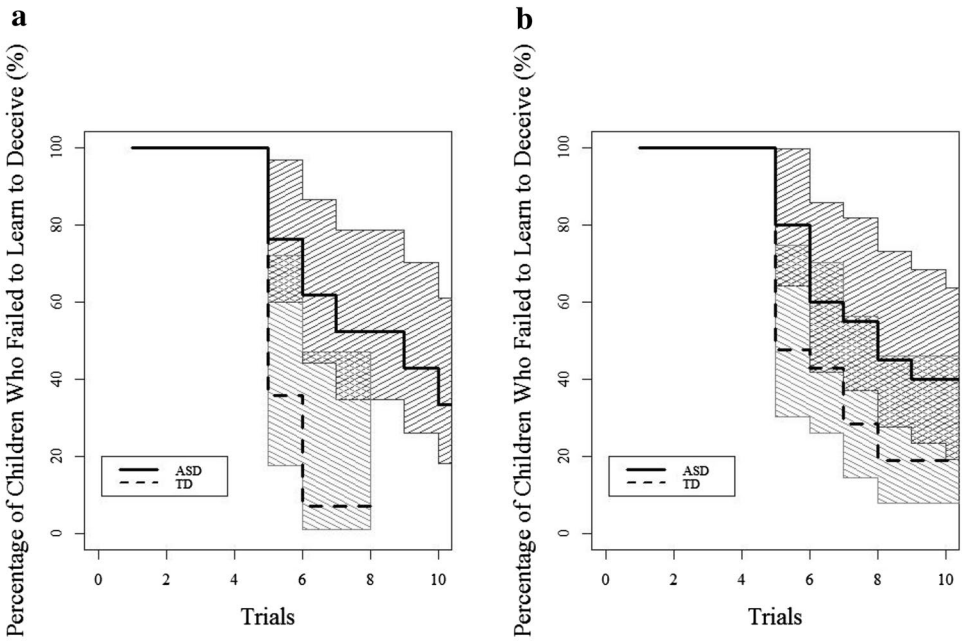

Fig. 5 Survival analyses. Percentages of children who failed to learn to deceive over trials in the social cue (**a**) and label the *empty box* in the non-social cue (**b**) conditions of the deception tasks. The *shaded areas* represent the 95% confidence intervals

the generalizability of these findings to lower-functioning children with ASD. Besides the social learning deficit, cognitive impairments may play a major role in both the social and non-social learning processes. Thus, the non-social learning could also be impaired in lower-functioning children with ASD. Our findings should also be interpreted with caution when extrapolated to children with ASD at different ages, as age plays an important role in children's development of trust and deception behaviors (e.g., Vanderbilt et al. 2011). Future research should include children with ASD with a broader age and IQ range, to investigate the developmental trajectory of social and non-social learning and the effect of cognitive dysfunction in this population. Fifth, our conclusions are based on a sample of Chinese children with ASD and TD children, so that cultural influences need to be taken into consideration when interpreting our findings. Generally speaking, Eastern and Western children exhibit highly similar distrust and deception behaviors (Fu et al. 2007; Xu et al. 2010), since both cultures generally encourage honesty and discourage deceit (Fu et al. 2010). However, subtle cultural variations of children's distrust and deception behaviors may exist, as a result of the emphasis on group harmony and collectivism in the East Asian culture (Rothbaum et al. 2000; Xu et al. 2010). For example, individualistic and collectivistic values influence the acceptability of lying, thus Chinese children prefer to lie to help the collective rather than the individual, while Canadian children do the reverse (e.g., Lau et al. 2013; Mealy et al. 2007; Sweet et al. 2010). Last, we used the between-subject design to minimize the learning generalization across conditions by randomly assigning the participants into the two conditions. With appropriate experimental designs, future research could compare one's performance in understanding the social vs. non-social cues using a within-subject design.

In summary, the current study aims to investigate whether reducing social cues could help ASD children overcome their deficits in trust and deception tasks. If so, this would provide evidence that their deficit in these tasks is more associated with their specific deficit in social learning than impairments in general learning ability. We found that the abnormalities in the distrust and deception behaviors in ASD are limited to the social situation, while their non-social learning is intact. Moreover, we found a social strength effect for TD children; their learning is benefited from the presence of social information. This social strength effect was absent in children with ASD due to their insensitivity to the social information. Besides, we also found a carry-over effect for TD children's non-social learning, which was absent in children with ASD. Overall, our findings support the social learning account of ASD (Bushwick 2001) in trust and deception behaviors. Our study has important implications for understanding the nature of ASD and interventions for individuals with the disorder. For example, when we train ASD children in social interactive tasks with similar complexity as our distrust and deception tasks, we should start with simple social cues in simple situations. After ASD children master the simple tasks, the training can incrementally include more social cues that are relatively challenging for them. Further work is needed to determine whether these findings could be generalized to a larger population of children with ASD.

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Author Contributions YY was responsible for data collection, data analysis, and manuscript preparation; YT was responsible for data analysis; JF was responsible for data collection; HL was responsible for data analysis and paper revision; KW was responsible for study design and manuscript preparation; LY was responsible for study design, data analysis, and manuscript preparation. All authors read and approved the manuscript.

Compliance with Ethical Standards

Conflict of interest All authors have no conflict of interest to declare.

Ethical Approval All procedures performed in this study were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all children included in the study and their parents.

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