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Approximating Implicit and Explicit Mentalizing with Two Naturalistic Video-Based Tasks in Typical Development and Autism Spectrum Disorder

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Abstract Individuals with autism spectrum disorder (ASD) have been proposed to show greater impairments in implicit than explicit mentalizing. To test this proposition, we developed two comparable naturalistic tasks for a performance-based approximation of implicit and explicit mentalizing in 28 individuals with ASD and 23 matched typically developed (TD) participants. Although both tasks were sensitive to the social impairments of individuals with ASD, implicit mentalizing was not more dysfunctional than explicit mentalizing. In TD participants, performance on the tasks did not correlate with each other, whereas in individuals with ASD they were highly correlated. These findings suggest that implicit and explicit mentalizing processes are separable in typical development. In contrast, in individuals with ASD implicit and explicit mentalizing processes are similarly impaired and closely linked suggesting a lack of developmental specification of these processes in ASD.

Keywords Autism spectrum disorder · Cognition · Mentalizing · Behavioral assessment · Implicit

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Introduction

The attribution of mental states to oneself and to others, also referred to as mentalizing, mental state attribution or theory of mind, represents one of the most important tools for successful social interaction (Premack and Woodruff 1978; Frith 1989).

Ever since the 'mindblindness' hypothesis has been put forward, suggesting that individuals with autism spectrum disorder (ASD) lack the ability to recognize another person's belief (Baron-Cohen et al. 1985, 1997), a large number of studies have investigated explicit mentalizing deficits in individuals with ASD using direct tasks that prompt participants to infer others' mental states. In those direct mentalizing tasks, participants are asked to infer a protagonist's mental state from stories (Happé 1993, 1994; Moran et al. 2011), photographs of persons' eye regions (Baron-Cohen et al. 2001), or from film scenes displaying social interactions (Dziobek et al. 2006).

Recently, the focus of interest in social cognitive research shifted from direct to indirect measures, i.e., to measures, where the construct of interest is inferred indirectly from another behavior (De Houwer and Moors

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2010). In contrast to direct measures, indirect tasks aim at approximating implicit processes, which are more efficient but also more inflexible than explicit processes (Apperly and Butterfill 2009). Please note that in the remainder of this article we refer to implicit and explicit for the respective cognitive processes that are reflected in social behavior, whereas we refer to indirect and direct for the types of measures that approximate theses processes.

Studies using indirect tasks provide increasing evidence for the notion that individuals with ASD show prominent impairments in processing social cues implicitly, i.e., in the absence of direct prompts (see Senju 2013 for a review). For example, research studies using gaze tracking report pronounced impairments of individuals with ASD in implicit social cognition (e.g., Jones and Klin 2009; Kirchner et al. 2011; Klin et al. 2009; Pitskel et al. 2011; Kirchner et al. 2011). The social cognitive deficits of individuals with ASD have been related to aberrant gaze patterns when looking at emotional face stimuli (Kliemann et al. 2010) or naturalistic social scenes (Klin et al. 2002). Using an indirect mentalizing task derived from game theory (the stag-hunt game), in which humans interacted with a computerized agent, Yoshida et al. (2010) found that the strategic behavior of individuals with ASD in a social cooperative game was less guided by implicit belief inference than in typically developed (TD) individuals.

Importantly, paralleling the observations of a differentiation between implicit and explicit mentalizing processes (Apperly and Butterfill 2009), individuals with ASD seem to show greater impairments in implicit as compared to explicit social cognition (e.g., Senju 2013). For instance, Kliemann et al. (2013) found that ASD participants showed greater deficits in implicit than in explicit facial emotion recognition, both assessed with comparable performance-based tasks. With regards to mentalizing, high-functioning individuals with ASD who did not show impairments on direct mentalizing tasks, showed a reduced spontaneous, i.e., implicit, capacity for belief inference (Schneider et al. 2013; Senju et al. 2009).

Up to now, however, it is largely unclear how implicit and explicit mentalizing processes can be distinguished and how they interact because previous studies either focused on only one of these processes or did not use comparable methodological formats that would allow unbiased comparisons (Frith and Frith 2012; Nosek et al. 2011). Furthermore, the abovementioned indirect mentalizing tasks only assess implicit processes in terms of how participants respond to other minds and ignore how well they understand those minds. The accuracy of such implicit processes, however, is important, as the goal of everyday social cognition is to draw accurate inferences to guide social behavior (Zaki and Ochsner 2011).

A shortcoming of most mentalizing tasks (both direct and indirect), concerns their abstract and mostly static stimulus material (see e.g., Castelli et al. 2002; Saxe and Kanwisher 2003). Abstract stimuli, such as written text or drawings, differ crucially from real life multimodal dynamic social cues that consist of visual and prosodic information embedded into a specific context that constrains our interpretations (Zaki and Ochsner 2009). Due to the lack of complexity, some static mentalizing tasks have been reported to produce ceiling effects in adult populations (Baron-Cohen et al. 1997). In contrast, naturalistic movie-based tasks may have the potential to produce the required amount of variability in the performance of typically developed (TD) adults, making it possible to investigate individual differences in mentalizing. Since the deficits of individuals with ASD are more pronounced in unstructured real life social situations (Volkmar et al. 2004) than in experimental settings, naturalistic video-based tasks approximating real life scenarios are more sensitive in picking up mentalizing deficits of individuals with ASD than standard, static tasks (Dziobek et al. 2006).

To summarize, there is some evidence suggesting that individuals with ASD show greater impairments in implicit as compared to explicit mentalizing. This is in line with the observation that individuals with ASD are characterized by severe impairments in real life social settings (Volkmar et al. 2004), where mentalizing most often occurs implicitly (Frith and Frith 2012). However, the interrelationships between implicit and explicit mentalizing processes in typical and atypical development remain unclear. This is due to lack of comparable indirect and direct tasks and because most standard mentalizing tasks to date are prone to ceiling effects in adults (Baron-Cohen et al. 1997), thus lacking sensitivity for a systematic comparison of implicit and explicit mentalizing processes in adult populations.

In this study we aimed at systematically comparing implicit and explicit mentalizing processes in TD individuals and individuals with ASD. We thus designed a direct and an indirect naturalistic movie-based task that allow the tracking of accuracy and reaction times (RTs) and thereby a comparison of intra- and interindividual performance differences (see Kliemann et al. 2013 for a similar approach). The tasks mainly differ in their answering format. After watching a social interaction, in the indirect task, participants are asked to solve a film puzzle by detecting the most likely continuation of the film scene out of four different film clip options. Importantly, there is no explicit prompt to infer mental states. In contrast, in the direct task, the participants are asked to watch film clips and select the most likely verbal explanation for the protagonists' emotional states.

In line with the definition by Fazio and Olson (2003), our indirect task approximates implicit processes by

Table 1 Demographic and symptom characteristics

	ASD (N = 28)				TD (N = 23)				
	N	M	MD	SD	N	M	MD	SD	p Value
Sex, F(N)/N	10/28	–	–	–	6/23	–	–	–	0.552
Age	28	33.07	33	8.45	23	32.43	30	8.86	0.795
MWT-IQ	28	113	107	16.40	23	108	104	12.91	0.313
ADOS	25	10.56	10	3.34	–	–	–	–	–
ASDI	25	42.00	43	4.76	–	–	–	–	–

M means, MD median, SD standard deviations, and N sample size of group characteristics

ASD autism spectrum disorder, TD typical development, F female, MWT Mehrfachwahl-Wortschatz-Test, − not applicable, ADOS autism diagnostic observation schedule, ASDI asperger syndrome and high functioning autism diagnostic interview

p values: two-tailed significance-value for t- and χ^2-tests in ASD vs. TD participants

seeking to provide information about the construct of interest without asking the participant to verbally report the desired information (see also Kliemann et al. 2013). To implement objective performance measures into the indirect task, we chose a narrower conceptualization of implicit processes compared to studies using indirect non-performance based measures, such as gaze tracking. Our indirect task involves the evaluation of multiple answer options in the absence of cues that prompt participants to verbally report the information of interest, and thus demand conscious processing. However, unconsciousness of the tested psychological construct is not necessarily a criterion for an implicit process (Fazio and Olson 2003; Nosek et al. 2011; Vierkant 2012).

Here we investigated the new tasks' sensitivity to atypical social cognition as well as possible dissociations between performance measured directly and indirectly. In line with previous studies, we expected the mentalizing impairments of individuals with ASD to be more pronounced in the indirect than in the direct task. In order to investigate the tasks' validity and to further differentiate between mentalizing measured directly and indirectly, we included two widely established direct mentalizing measures, a performance and a self-report measure. We expected individuals with ASD to perform significantly lower than TD participants on both direct and indirect tasks. In accordance with the notion that implicit and explicit mentalizing processes are distinguishable, we expected the established direct mentalizing measures to be more strongly related to direct than to indirect task performance.

Methods

Participants

Twenty-eight adults with ASD (18 men, mean age = 33.1) and 23 TD participants (17 men, mean age = 32.4) with no

reported history of psychiatric or neurological disorders participated in the study. The ASD participants were recruited through the autism outpatient clinic of the Charité—Universitätsmedizin Berlin, Berlin, Germany, or were referred by specialized clinicians. All participants were diagnosed according to the DSM-IV criteria for Asperger syndrome (N = 25) and autism without intellectual disability (N = 3) (American Psychiatric Association 1994). Diagnosis was confirmed by at least one of two instruments that are considered the gold standard for diagnosing autism: the Autism Diagnostic Interview—Revised (ADI-R; Lord et al. 1994), if parental informants were available (N = 15), and the Autism Diagnostic Observation Schedule (ADOS, Lord et al. 2002) (N = 25). For 25 ASD participants, the diagnosis of Asperger syndrome or high-functioning autism was additionally confirmed with the Asperger Syndrome and High-Functioning Autism Diagnostic Interview (ASDI, Gillberg et al. 2001). The groups were matched according to gender, age, and verbal IQ (see Table 1), as measured by the Mehrfachwahl-Wortschatz-Test (MWT; Lehrl 1989), a German vocabulary test. All of the participants gave written informed consent prior to their participation and received payment for participating. The study was approved by the ethics committee of the German Society for Psychology (DGPs).

Materials

The Arena of Emotions Tasks

In this study we aimed at systematically comparing implicit and explicit mentalizing processes with the newly developed Arena of Emotions indirect and direct tasks, respectively. Both tasks approximate real-life settings more closely than text or photo-based tasks, have a similar structure and use similar material. The main difference between the tasks is whether or not they contain prompts that ask participants to verbally report the protagonists'

A: Example item for indirect task.

Each video item is preceded by a short written introduction, describing the context and setting of the interaction

Written Introduction: Julia and Tim have been a couple for three years. They are very happy and respectful with each other. It is Tim's birthday today and together with a friend he is waiting for Julia.

Film clip content: Tim's friend asks whether he has bought himself the new computer game he wanted. Tim replies that he did not. He states that he is sure Julia has bought him the game for his birthday. Julia comes in with a present. Tim opens it excitedly and discovers that she got him a pullover.

Task: Participants are asked to watch the 4 film clips and pick the best-suited option as to how the scene might continue.

Correct answer: Option 2; Tim's facial expression initially shows disappointment. Then, he smiles and thanks Julia for the gift.

B: Example item for direct task.

Each video item is preceded by a short written introduction, describing the context and setting of the interaction

Written Introduction: Dinah's friends are helping her to move out today. They do not know that she has to pay a fine if she is not done by noon. The three friends are in Dinah's apartment.

Film clip content: Dinah's friends take their time chatting about a vacation. Dinah urges them impatiently to stop talking and to start working instead.

Task: Participants are asked to pick one out of four text options that correctly describe what Dinah's friends are feeling at the moment when the film clip stops.

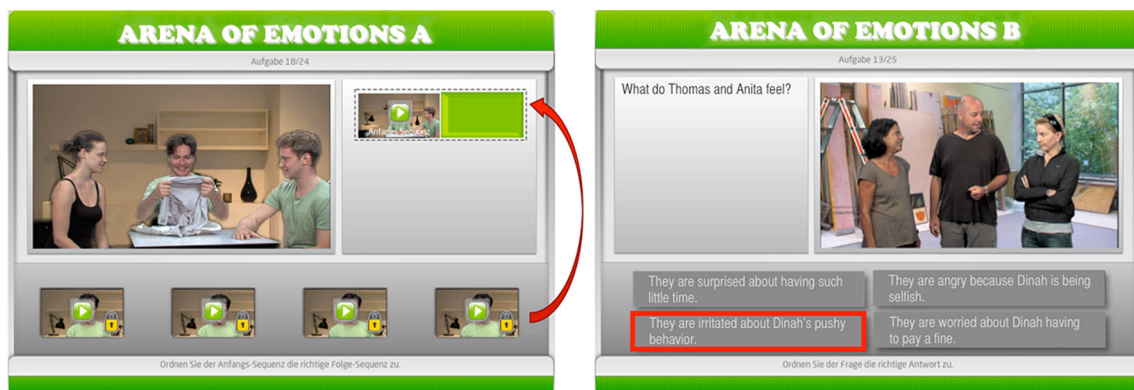**Correct answer**: Option 3; "Thomas and Anita are irritated about Dinah's pushy behavior."

Fig. 1 The arena of emotions tasks. **a** Example item for indirect task. **b** Example item for direct task

mental states. The direct task contains explicit cues that prompt participants to select one of four possible mental state labels, whereas the indirect task involves the conscious evaluation of multiple answer options in the absence of explicit, verbal cues. Given that most social behavior lies on a continuum between implicit and explicit, cognitively controlled processing (Cunningham and Zelazo 2007; Cunningham et al. 2007), implicit mentalizing assessed with the indirect task in this study can be regarded as more implicit than the behavior assessed with the direct task, which includes the conscious evaluation of direct cues that prompt participants to label mental states including the respective rationales.

The items of both tasks consist of short film clips (mean duration 21.6 s, SD = 5.2, range 9–31 s) depicting everyday social interactions (e.g., colleagues taking a lunch break or friends discussing holiday plans), preceded by a short written introduction that describes the context (e.g., the relationship between the protagonists) and the setting of the interaction (e.g., the interaction takes place at work during a lunch break). We used independent film sets with similar content, design and the same actors for both the direct and the indirect task. The tasks were designed in cooperation with a digital agency (gosub communications gmbh, http://www.gosub.de/) to make them graphically appealing. The tasks were furthermore programmed as web applications to increase their accessibility because no stand-alone installation is required, and to facilitate their modification and distribution. The web-based assessment further ensures that all generated output is stored in a central database, which allows users to accumulate and organize large data sets. The tasks can be accessed on a public webserver through any browser with the Flash Player plugin installed. The indirect task took approximately 14 min and the direct task 20 min to complete. Although no time limits are set for the completion of either task, the participants are instructed at the beginning of each task to perform as quickly and accurately as possible.

In the 24-item indirect task, participants first watch a film scene and subsequently four short film clips (4 s) displaying different options for how the scene might continue. The participants then have to use the computer mouse to select the film clip that represents the most likely continuation and to place it into the target panel using a drag-and-drop function (see Fig. 1). Thus, the indirect task instruction is to simply solve a film puzzle with no explicit information about the protagonists' emotional or mental states. The RTs in this task represent the time to watch the four different video options and drag-and-drop the selected video option into the target field.

In the 25-item direct task, participants also first watch a film scene. In contrast to the indirect task, the direct task contains cues that explicitly direct the participants to infer others' mental states (e.g., How do Thomas and Anita
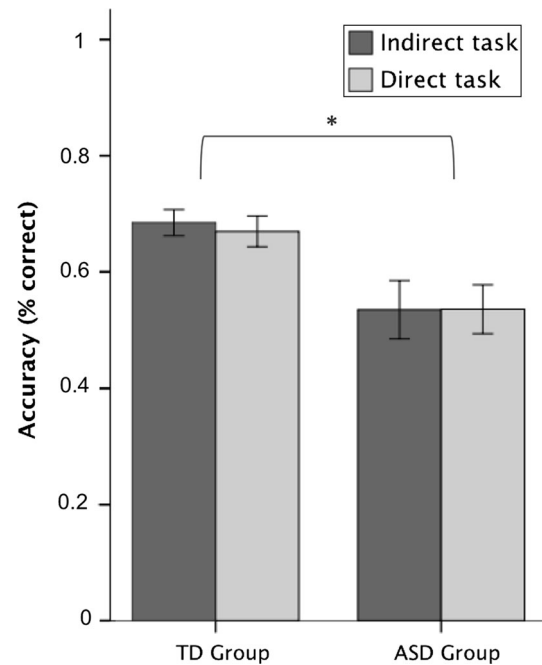

Fig. 2 Accuracy scores of the direct and indirect tasks. Mean accuracy scores in the Arena of Emotions tasks in Controls and ASD. Accuracy scores in the indirect and direct Arena of Emotions tasks differ significantly between groups. *Asterisk* significant difference between controls and ASD ($p < 0.05$); *ASD* autism spectrum disorder

feel?). That is, after having watched the initial film clip, participants are asked to select one of four text options that gives the best explanation for a protagonist's emotional state at the moment the film stops. RTs in the direct task are tracked from the time when the response options appear on the screen until the participants respond by making a selection via mouse click. Due to differences in task format RTs differ systematically between the indirect task and the direct task (paired t test on RTs over all participants: t (1, 50) = 14.112, $p < 0.001$).

Since mentalizing errors can either reflect insufficient mental state inferences ("under-mentalizing") or the tendency to over interpret mental states ("over-mentalizing") (see Frith 2004; Sharp and Venta 2012), we have designed our distractor items accordingly of both direct and indirect tasks. Distractors were designed to represent three types of errors: (A) mental state inferences that are "too excessive" (i.e. "overmentralizing"), e.g., interpreting a mistake as intentional rather than accidental; (B) mental state inferences that are "insufficient" (i.e. "undermentalizing"), e.g., underestimating the consequences of disrespectful behavior; and (C) non-mental state inferences, i.e., the inferences are not directly related to the mental states of the protagonists in the previous interaction (for a similar approach, see Dziobek et al. 2006).

To ensure that both tasks are comparable with regards to the overall item difficulty and distribution, they were

Table 2 Social cognition measures in TD and ASD participants

	Arena of emotion indirect task		Arena of emotion direct task		RMET[a]	PT (IRI)
	Accuracy	*cRT (s)*	*Accuracy*	*cRT (s)*	*Accuracy*	*Mean rating*
TD (N = 23)						
M	0.68	21.73	0.67	10.10	0.71	25.70
MD	0.71	21.43	0.68	9.62	0.72	25.00
SD	0.11	4.46	0.13	3.56	0.10	3.91
ASD (N = 28)						
M	0.53	21.09	0.54	12.44	0.60	19.86
MD	0.54	19.97	0.60	9.31	0.64	20.00
SD	0.27	12.57	0.22	10.99	0.18	5.15
p value	**0.010***	0.806	**0.014***	0.296	**0.011***	10^{-5}***

RMET reading the mind in the eyes test, *PT* perspective taking scale, *ASD* autism spectrum disorder, *M* means, *MD* median, *SD* standard deviations, and *N* sample size

p values two-tailed significance-value for t-tests ASD versus controls; * significant difference between controls and ASD ($p < 0.05$), *** significant difference between ASD and controls ($p < 0.001$)

[a] Number of ASD participants differs for the RMET: N(ASD) = 24

piloted in a separate validation study with an additional sample of TD participants (N = 28). Based on the results of the validation study, items that lacked sensitivity (i.e., produced ceiling or floor effects) were revised by changing the introduction information and/or the answer options. A detailed description of the stimulus production and validation processes is included in the supplementary material.

To assess the validity of the Arena of Emotions direct and indirect tasks and further differentiate between the assessed processes, we additionally included two established direct mentalizing measures into the study. The Reading the Mind in the Eyes Test (RMET, Baron-Cohen et al. 2001) is a performance-based measure that requires participants to label the mental state of a person based on the information conveyed in photographs of that person's eyes. Thus, the RMET aims at inferring and explicitly labeling mental states, similar to our direct task. We further assessed participants' awareness of their perspective-taking ability using the 'Perspective Taking' (PT) subscale of the 'Interpersonal Reactivity Index' (IRI) (German translation, Paulus 2006). The PT subscale consists of 7 items answered on a 5-point Likert scale. The statements included in this scale, e.g. "I try to look at everybody's side of a disagreement before I make a decision", requires explicit insights into one's own perspective-taking abilities.

Procedure

The participants completed the Arena of Emotions direct and indirect tasks online through the project's website in testing rooms under the supervision of trained experimenters. The task order and the position of the four answer options in each task were counterbalanced across participants to control for possible order effects. Both direct and indirect tasks start with a few introduction slides that describe the procedure. Throughout the entire test, participants use the mouse only to read the introduction or solve and proceed to the next item.

The scores, e.g. accuracy scores and RTs for each testing session are automatically saved to an online database for each of the two tasks independently. The datasheets can then be exported, downloaded, and further analyzed with a statistical program such as SPSS (IBM SPSS Statistics, Armonk, NY: IBM Corp.).

Furthermore, participants completed web-based versions of the MWT, IRI, both accessible through the project's website, and the computer-based RMET, presented using Presentation (Version 14.1, Neurobehavioral Systems Inc., Albany, CA).

Results

All variables of interest reported in the results section were normally distributed and met criteria for parametric analyses.

Reliability Analysis

Both the direct and indirect tasks yielded good internal consistency (direct task: Cronbach's $\alpha = 0.82$; indirect task: Cronbach's $\alpha = 0.84$).
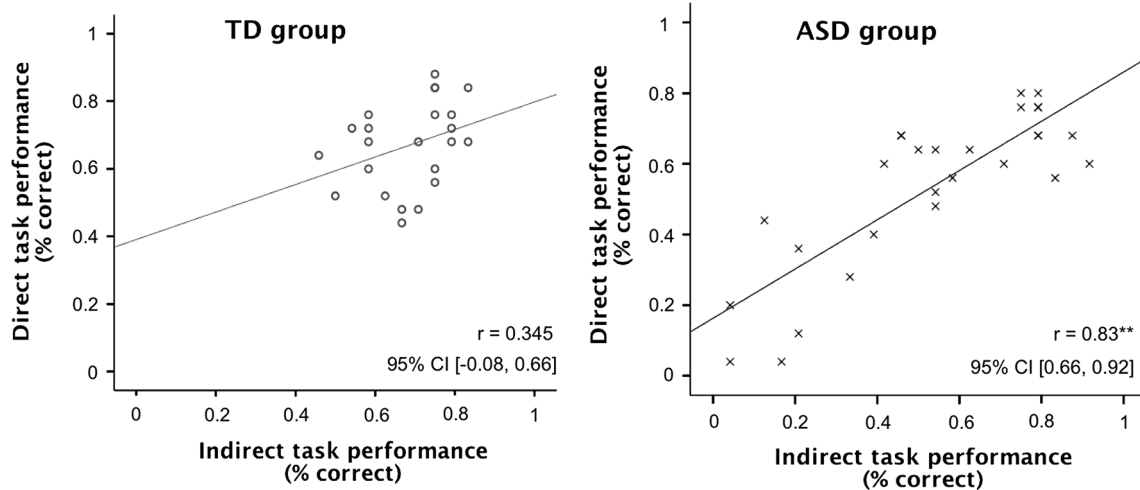
Fig. 3 Relationship between the accuracy scores of the indirect and direct tasks. In the ASD group accuracy scores in the indirect and direct task are significantly correlated, in controls they are not correlated. The correlation coefficients differ significantly between groups. *ASD* autism spectrum disorder

Tasks' Sensitivity to Atypical Emotion Recognition

Accuracy

We performed a repeated-measures ANOVA on accuracy rates with the within-subject factor condition (direct versus indirect task) and the between-subject factor group (TD versus ASD). On both tasks, the ASD group had significantly fewer correct responses compared with the TD group (main effect of group, $F(1, 49) = 7.410$, $p = 0.009$, $\eta_p^2 = 0.131$; see Fig. 2). Participants' accuracy rates did not differ between the indirect and the direct task conditions [no main effect of condition, $F(1, 44) = 0.127$, $p = 0.723$; no interaction between group and condition, $F(1, 44) = 0.161$, $p = 0.69$; see Table 2]. Furthermore, the ASD group's performance on both tasks was negatively correlated with autism symptomatology at trend level [ADOS and direct task: $r = -0.387$, $p = 0.056$, 95 % CI $(-0.826$–$0.010)$; ADOS and indirect task: $r = -0.469$, $p = 0.018$, 95 % CI $(-0.729$–$0.091)$; ASDI and direct task: $r = -0.379$, $p = 0.062$, 95 % CI $(-0.673$–$0.019)$; ASDI and indirect task: $r = -0.354$, $p = 0.083$, 95 % CI $(-0.657$–$0.048)$], indicating that more severely affected individuals scored lower on both tasks.

Reaction Times

Mean RTs for correct responses were calculated for each participant in both tasks and are referred to as RTs. Trials with incorrect responses were excluded from further analyses. There were no group differences in RTs for correctly solved items in either of the tasks [direct task: $t(1, 34) = -1.061$, $p = 0.296$; indirect task: $t(1, 35) = 0.248$, $p = 0.806$, see Table 2].

Gender Differences Within the ASD Group

Given recent evidence of gender differences in social cognition in ASD (e.g., Sucksmith et al. 2013) and a relatively large proportion of females in our sample, we analyzed gender differences within the ASD group in an exploratory fashion. As symptom severity and verbal IQ represent potential confounds, we included these as covariates into the analysis. Male and female ASD participants did not differ with respect to symptom severity assessed with the ADOS [$t(1, 23) = -1.256$, $p = 0.222$] and ASDI [$t(1, 23) = -0.897$, $p = 0.379$]. They also scored similarly on the verbal IQ measure [$t(1, 26) = -1.091$, $p = 0.285$]. To investigate the tasks' sensitivity to gender differences within the ASD group, we performed a repeated-measures ANOVA on accuracy rates with the within-subject factor condition (direct versus indirect task) and the between-subject factor gender (males versus females). ASD males and females showed comparable performance on the direct and indirect task [main effect of condition, $F(1, 26) = 0.018$, $p = 0.894$; interaction of gender and condition, $F(1, 26) = 0.133$, $p = 0.718$]. On both tasks, females had significantly fewer correct responses than males [main effect of group, $F(1, 26) = 6.609$, $p = 0.016$, $\eta_p^2 = 0.203$]. When entering ADOS, ASD and verbal IQ scores as covariates into the analysis, the group difference in performance between males and females remained significant [$F(1, 17) = 4.581$, $p = 0.047$, $\eta_p^2 = 0.212$].

Correlation Analysis

We analyzed correlations separately for the two groups because groups differed significantly in their performance on all social cognition measures (see Table 2).

The Relationship Between Direct and Indirect Task Performance

The direct and indirect Arena of Emotions task accuracy scores were not correlated in the TD group [$r = 0.345$, $p = 0.106$, 95 % CI (-0.078–0.663)], but significantly correlated in the ASD group [$r = 0.829$, $p < 0.01$, 95 % CI (0.660–0.918)]. The correlations differed significantly between groups, reflecting differences in the relationship between implicit and explicit mentalizing processes in individuals with ASD and TD individuals (Fisher's r-to-z = 2.75, $p < 0.01$, see Fig. 3).

The Tasks' Relationship with External Measures

To investigate the tasks' validity and further differentiate between performance measured directly and indirectly, we correlated both direct and indirect task accuracy scores with scores from established direct social cognition measures, such as the RMET and the PT subscale of the IRI, which assess participants' explicit judgment of their perspective taking tendencies.

Among TD participants, Arena direct task performance correlated significantly with accuracy on the RMET [$r = 0.417$, $p = 0.048$, 95 % CI (0.006–0.708)]. In contrast, the correlation between accuracy scores on the indirect task and on the RMET did not reach significance [$r = 0.303$, $p = 0.160$, 95 % CI (0.006–0.708)]. However, the difference between the correlations was not significant [Williams' T$_2$: t (20) = -0.493, $p > 0.05$]. In the ASD group, accuracy scores on both direct and indirect tasks was significantly correlated with performance on the RMET [RMET and indirect task: $r = 0.681$, $p < 0.001$, 95 % CI (0.413–0.841); RMET and direct task: $r = 0.791$, $p < 0.001$, 95 % CI (0.593–0.899)].

PT correlated negatively with indirect task accuracy scores in the TD group ($r = -0.421$, $p = 0.045$, 95 % CI (-0.710–0.010)], suggesting that participants with higher accuracy scores on the indirect task reported explicit perspective-taking tendencies less frequently. In contrast, PT was not significantly correlated with accuracy scores on the direct task [$r = 0.253$, $p = 0.245$, 95 % CI (-0.178–0.602)]. The difference between these correlations in the TD group was significant [Williams' T$_2$: t (20) = -3.282, $p < 0.01$]. In the ASD group, PT did not correlate significantly with either indirect task accuracy [$r = 0.128$, $p = 0.517$, 95 % CI (-0.257–0.478)] or direct task accuracy scores [$r = 0.280$, $p = 0.149$, 95 % CI (-0.104–0.591)].

Discussion

In the current study, we developed two naturalistic, comparable tasks for a performance-based approximation of implicit and explicit mentalizing with an indirect and direct task, respectively. In TD participants, both tasks produced the required amount of variability in performance, showing that the naturalistic tasks are a sensitive means of assessing mentalizing in a TD adult population. The tasks were also sensitive to the social cognitive impairments of individuals with ASD. ASD participants gave significantly less correct responses and accuracy scores were negatively correlated with symptom severity at a trend level, suggesting that more impaired individuals scored lower. Finally, the relationship between direct and indirect task performance differed significantly between groups. In the TD group, performance scores on the direct and indirect tasks did not correlate, indicating that the underlying processes are to some degree distinguishable. In the ASD group, performance scores on the direct and indirect task were highly intercorrelated, suggesting a lack of differentiation between implicit and explicit processes.

Individuals with ASD are characterized by atypical social cognition throughout development (e.g., Baron-Cohen 2001; Baillargeon et al. 2010) and thus constitute a highly appropriate clinical population for studies on implicit and explicit mentalizing processes, which have been proposed to differentiate early on in TD individuals (Low and Perner 2012). As expected and in line with a great body of literature (Happé and Frith 1996; Hill and Frith 2003; Senju 2013), individuals with ASD scored significantly lower on the direct and indirect task than the TD comparison group, with more impaired individuals scoring lower than less impaired individuals. In contrast to our expectations, which were based on previous studies (Senju et al. 2009; Callenmark et al. 2013), we did not find an interaction between task and group, suggesting that individuals with ASD were not more impaired in implicit than in explicit mentalizing. Both previous studies showed that individuals with ASD had impairments in implicit, spontaneously occurring mental state inferences, although they were capable of explicit mentalizing. Importantly, however, the direct and indirect tasks used in those studies varied widely in format and were thus less comparable in differentiating between implicit and explicit mentalizing processes. More specifically, both studies used highly structured and static direct tasks and unstructured, more dynamic indirect tasks. For example, in the study by Senju et al. (2009) aberrant implicit mentalizing processing was inferred from a lack of visual attention anticipating where a protagonist in a film clip would look for a hidden object. In contrast, the direct mentalizing tasks used in this study assessed whether participants were able to pass static false belief tasks. Given that the deficits of individuals with ASD are more pronounced in unstructured dynamic settings (Volkmar et al. 2004), the observed differences between implicit and explicit mentalizing could result from differences in the task formats. The simple false belief tasks used Senju et al. (2009), such as the Sally-Ann task by Baron-Cohen et al. (1985), have been

shown to produce ceiling effects in participants with a mental age above 6 years (Baron-Cohen et al. 1997) and therefore may not have been sensitive enough to capture differences between groups. With respect to the more advanced Strange Stories test by Happé (1994), the authors used a small subsample (8 stories) out of the total set of 24 stories. This could have additionally led to a more restricted range in the performance scores of ASD and control participants. In contrast, explicit video-based tasks are less structured and thus provide a more sensitive assessment of social cognitive impairments in high-functioning individuals with ASD. Using a movie-based task, Dziobek et al. (2006) found that individuals with ASD were less accurate at answering explicit questions referring to the actors' mental states compared to TD controls. Moreover, the movie-based task was more sensitive in picking up mentalizing difficulties of individuals with ASD than static tasks such as the Strange Stories test or the RMET. Altogether, these results stress the importance of using more challenging, naturalistic mentalizing tasks that produce the required amount of variability to reliably assess implicit and explicit mentalizing in both TD adults and in adult populations with socio-cognitive impairments. Exploratory analyses of gender differences in the autistic sample yielded significantly higher performance on both direct and indirect tasks of male ASD participants compared to females. Recently, a growing number of studies have reported gender differences within ASD on various behavioral measures including cognitive abilities (Boelte et al. 2011; Lai et al. 2011; Lord et al. 1982) and social cognition in particular (Carter et al. 2007; Golan et al. 2006, 2007; Sucksmith et al. 2013). In contrast to our results, previous studies have found higher facial emotion recognition performance in adult females with ASD compared to males (Golan et al. 2006; Sucksmith et al. 2013). However, in line with our results, Carter et al. (2007) found that parents reported higher social competences for boys with ASD than for girls and Golan et al. (2007) report higher performance on a naturalistic emotional prosody task in autistic males compared to females. Thus, in more complex naturalistic settings, such as inferring mental states from speech and videos, or interacting in real life situations, autistic males seem to have an advantage over females. Given that males have a higher tendency to systemize compared to females (Auyeung et al. 2012; Baron-Cohen et al. 2003) a possible explanation for this gender difference could be that autistic males benefit from higher systemizing skills in complex naturalistic settings. More specifically, males with ASD might use their systemizing skills to make sense of social cues by e.g. applying social norms, rather than processing them intuitively. Such strategies, however, require social stimuli to be relatively complex and thus might not be applicable to reduced static stimuli. In this study, we did not assess participants' potential task solving strategies and also we did not assess systemizing tendencies in our sample. To investigate this hypothesis, future studies should include larger samples of males and females with ASD and assess systemizing tendencies as well as performance on a wide range of basic and more complex social cognition measures.

With regards to the relationship between implicit and explicit aspects of mentalizing, accuracy scores on the direct and indirect tasks were not correlated in healthy individuals. These findings are in line with previous assumptions of a distinction between implicit and explicit social cognition (Adolphs 2009; Apperly and Butterfill 2009; Low and Perner 2012; Kliemann et al. 2013). In individuals with ASD, performance scores on the direct and indirect task were significantly intercorrelated. The correlations between indirect and direct task scores differed significantly between groups indicating group differences in the relationship between implicit and explicit mentalizing processes. However, TD individuals in our sample had a more restricted performance range than the ASD participants and this could at least partly explain the between group difference in the strength of correlations. By matching the groups for gender, age and verbal IQ, we controlled for demographic differences between groups, and thus believe that the greater variance in the performance of ASD participants reflects a wider spectrum of socio-cognitive abilities among individuals with ASD compared to the TD population.

In typical development implicit mentalizing develops during the first year of life (e.g., Kovács et al. 2010) and is seen as a precursor to explicit mentalizing, i.e., giving the correct reasoning for a person's (false) belief (Clements et al. 2000; Low and Perner 2012; Thoermer et al. 2012). Young infants, for example, track the beliefs of others (Kovács et al. 2010; Onishi and Baillargeon 2005) without necessarily being able to make correct explicit belief inferences (Ruffman et al. 2001). During adulthood, implicit and explicit mentalizing processes seem to coexist mediating distinct features of social cognition. For example, Samson et al. (2010) reported that adults track another person's perspective, even when they are explicitly instructed to focus on their own perspective.

Our assessment of the relationship between the participants' performance on the newly designed tasks and established direct social cognition measures provides further evidence that implicit and explicit mentalizing processes can be differentiated to a certain degree by behavioral measures in TD individuals. The TD group's performance on the direct task correlated with the RMET test scores, suggesting that both measures might assess similar explicit processes. This result also provides an external validation of our newly developed direct task. In contrast, indirect task performance and RMET scores were not significantly correlated. However, the correlations

between RMET and direct task performance and RMET and indirect task performance did not differ significantly from each other. This indicates that implicit and explicit processes, assessed with these newly developed tasks, are distinguishable but not completely independent of each other. In addition, TD participants' subjective judgment of their own perspective taking tendencies was negatively correlated with performance on the indirect task, but not with performance on the direct task. The significant difference between these correlations further indicates a distinction between the mentalizing processes assessed directly and indirectly. The lack of a positive correlation between direct task performance and the self-report perspective taking scale could be due to a discrepancy between objective test measures and subjective judgments of one's own tendencies. Subjective self-report measures are useful in detecting self-views but may not accurately reflect socio-cognitive abilities. Such a discrepancy between self-report and more objective performance tests have been already shown in the domain of social cognition (e.g., Brackett et al. 2006). The negative correlation between indirect task performance and subjective judgment of one's own perspective taking tendency suggests that the higher participants' awareness of how they infer someone else's mental state, the lower they scored on the indirect task. Our indirect task involves solving film puzzles. While watching film clips depicting complex social interactions participants infer protagonists' mental states spontaneously (Klin et al. 2002). Hence, individuals, who are less analytical and thus reflect less about their perspective-taking strategies, could perform better on a task that requires them to spontaneously track mental states while finding the matching film sequence.

In contrast, individuals with ASD show severe impairments in implicit social cognitive processes in early development. Young infants with ASD do not show a looking preference for humans as compared to objects (e.g., Swettenham et al. 1998) and do not share someone else's attention to an object, i.e. joint attention (Charman et al. 1997). Such implicit social cognitive tendencies have been identified as precursors to explicit knowledge about others' mental states (Clements et al. 2000; Low and Perner 2012; Thoermer et al. 2012). Impairments in implicit mentalizing processes, such as joint attention, could thus lead to the observed impairments and delays in explicit mentalizing. The link between implicit and explicit mentalizing would thus reflect common pervasive socio-cognitive impairments underlying both implicit as well as explicit aspects of social cognition. To address this notion, there is a need for longitudinal investigations of implicit and explicit mentalizing in individuals with ASD with comparable performance based tasks.

In individuals with ASD, accuracy scores on the indirect and direct tasks correlated significantly with performance on the RMET and did not correlate with self-reported perspective taking tendencies. These findings provide further evidence of a lack of differentiation between implicit and explicit mentalizing processes as well as a lack of correspondence between subjective self-reported mentalizing abilities and objectively measured mentalizing in individuals with ASD, which is possibly due to a lack of introspection into their social-cognitive deficits. For instance, self-reported symptom severity does not adequately differentiate autistic patients form other patient groups (Ketelaars et al. 2008) and does not correlate with scores on a standard diagnostic instrument, such as the ADI-R (Bishop and Seltzer 2012).

Our findings seem to indicate that individuals with ASD have comparable impairments in implicit and explicit mentalizing and that therefore both processes deserve attention in therapeutic and intervention settings, such as social competence trainings (Frith and Frith 2012). To date, existing social competence trainings are mainly direct, training individuals to label emotional facial expression or emotional prosody (e.g., Golan and Baron-Cohen 2006). These training interventions mainly produce improvements on close generalization tasks that are very similar to the training material, without generalizing to other social-cognitive tasks or to everyday social functioning (Golan and Baron-Cohen 2006; Hadwin et al. 1997). It is possible that effects of social trainings that include indirect tasks and naturalistic stimuli that more closely approximate the complexity and dynamics of real-life social cues compared to tasks using abstract stimulus material could generalize across a greater number of tasks and contexts.

In summary, we took a systematic approach towards comparing mentalizing processes measured directly and indirectly. To this end, we developed and carefully validated two comparable and sensitive tasks for a performance-based approximation of implicit and explicit mentalizing. Using these tasks, we showed that implicit and explicit mentalizing are similarly impaired in individuals with ASD. Furthermore, assessing TD individuals and individuals with ASD with the direct and indirect tasks, we further specified the relationship between explicit and implicit mentalizing processes in typical and atypical development. Our results suggest that implicit and explicit mentalizing processes seem to be distinct to a certain degree in healthy individuals, whereas in individuals with ASD implicit and explicit processes seem to be more closely linked. In conclusion, naturalistic tasks are a sensitive means to address the pervasive mentalizing impairments of individuals with ASD, which concern both explicit and implicit mentalizing processes. Thus, there is a need to include dynamic naturalistic tests into social cognitive test batteries, trainings, and interventions.

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