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ORIGINAL PAPER

Stimulus Characteristics Affect Humor Processing in Individuals with Asperger Syndrome

Andrea C. Samson · Michael Hegenloh

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Abstract The present paper aims to investigate whether individuals with Asperger syndrome (AS) show global humor processing deficits or whether humor comprehension and appreciation depends on stimulus characteristics. Non-verbal visual puns, semantic and Theory of Mind cartoons were rated on comprehension, funniness and the punchlines were explained. AS individuals did not differ to the control group in humor appreciation of visual puns. However, they had difficulty understanding and appreciating Theory of Mind cartoons and provided mentalistic explanations less frequently than controls suggesting that humor processing is strongly related to the cognitive requirements that the stimuli pose on the perceiver. Furthermore, AS individuals referred in all conditions more frequently to non-joke relevant details. Therefore, humor processing is also influenced by their detail-oriented processing style.

Keywords Asperger syndrome · Humor · Theory of mind · Cartoons · Empathizing · Local–global processing

Introduction

Individuals with Asperger syndrome (AS) are known to have problems in social interaction. Humor can be seen as an important tool in social interaction, supporting relationships but also communicating indirectly opinions that cannot be expressed overtly. In order to understand and appreciate humorous stimuli, several cognitive abilities are required, such as an abstract understanding of ideas and the capacity to integrate information into a new concept (see also below). The present study investigated humor processing in individuals with AS and sought to identify the underlying mechanisms that might lead to possible deficits in processing and appreciating humor.

Early notions on humor skills in relation to individuals with AS suggested that they do not understand humor (Asperger 1944). Meanwhile, experimental and case report studies on humor appreciation in individuals with AS, as well as autism have lead to a more fine-grained picture: individuals with autism and AS enjoy slapstick comedy and simple jokes (Ricks and Wing 1975) and mildly autistic adults have a good, albeit not very subtle, sense of humor (Everard 1976). Recently, Werth et al. (2001) described a female with high functioning autism (HFA) who conspicuously often produced puns, jokes, neologisms and word plays as well as used riddles, teasing, sarcasm and irony. In addition, several empirical investigations have shown that certain forms of humor exist in individuals with autism or AS: Van Bourgondien and Mesibov (1987) reported that high-functioning autistic adults tell jokes that are on a lower humor stage than their actual age (e.g., pre-riddles or jokes based on lexical and phonological incongruities). Furthermore, Baron-Cohen (1997) demonstrated that individuals with autism persistently fail to "get the joke" and that they do not refer to the speaker's intention to joke. St. James and Tager-Flusberg (1994) showed that children with autism can produce and appreciate humor to a limited extent in naturalistic settings: no differences were found in earlier forms of humor (e.g., humor based on rhyme, slapstick,

A. C. Samson (✉) · M. Hegenloh
Department of Psychology, University of Fribourg,
Rue Faucigny 2, 1700 Fribourg, Switzerland
e-mail: andrea.samson@unifr.ch

Present Address:
M. Hegenloh
General and Experimental Psychology,
Ludwig-Maximilians-University, Munich, Germany

funny sounds) but in nonverbal incongruity and riddles (children with autism produced no riddles at all). Another study showed children with autism laugh as much as children with Down's syndrome in response to tickling and slapstick humor, but exhibit less laughter in response to socially inappropriate acts (Reddy et al. 2002). In a more experimental setting, two studies showed that comprehension of humorous material is poorer in individuals with AS or autism than controls (Ozonoff and Miller 1996; Emerich et al. 2003). The participants had to choose one out of five possible funny joke endings. Individuals with AS had poorer comprehension of cartoons and jokes. Instead of choosing the correct funny ending, they most frequently chose humorous, but not coherent endings.

The aim of the present study is to establish which cognitive or affective deficits cause impairments in humor processing in individuals with AS and how strongly humor processing in individuals depends on cognitive requirements the stimuli pose on the perceiver. Differences in the stimuli and tasks used in previous studies might have lead to different conclusions: Generally, it is assumed that those individuals with AS and autism who have highly developed linguistic and computational abilities approach humor from a more cognitive/intellectual perspective and are able to grasp the cognitive basis of humor (e.g., such as recognizing violations of linguistic and logical principles; for a review, see Lyons and Fitzgerald 2004). However, the underlying mechanisms for the impairments, particularly in more complex forms of humor, are controversially discussed: for example, St. James and Tager-Flusberg (1994) assumed that the reduced humor processing skills derive from difficulties in social-cognitive deficits in understanding mental states (see also Baron-Cohen et al. 1993), whereas Reddy et al. (2002) assumed that difficulties in mutual attention and emotion sharing cause these effects rather than symbolic and meta-representational skills. Emerich et al. (2003) claimed that deficits in humor processing arise due to impairments in cognitive flexibility and coherence building, as these skills are necessary in order to reinterpret the meaning of parts of the joke.[1]

Which cognitive processes are necessary in order to "get" a joke? According to psychological and also cognitive-linguistic humor theories an incongruity, i.e., a conflict between two initially opposed scripts or schemas, has to be detected and then playfully resolved by recognizing a relation between the two scripts (e.g., Suls 1972; Shultz 1976; McGhee et al. 1990; Attardo and Raskin 1991). In order to resolve an incongruity, cognitive rules, also called logical mechanism (LM) have to be recognized (e.g., that a joke is based on role exchange or analogy, etc.). LMs are of particular interest in the present study. Previous studies (Samson et al. 2008; Samson 2009) showed that different LMs have different cognitive requirements which were shown to influence neural activation patterns. Visual puns (PUN, which are based on one visual element simultaneously evoking two meanings) were shown to evoke more activation in the visual cortex whereas TOM cartoons (TOM, they require additional mentalizing skills in order to be understood: it has to be recognized that one character portrayed in the cartoon has a false mental state) require more involvement of so-called "mentalizing areas" [e.g., medial prefrontal cortex, temporo-parietal junction (TPJ)]. Semantic cartoons (SEM: the incongruity is based on pure semantic (not visual) relations between two scripts and the incongruity can be resolved by applying a LM, such as role reversal, juxtaposition or exaggeration) evoke activation in the typical humor processing areas (e.g., inferior frontal gyrus, TPJ, see Samson et al. 2008). The three groups of cartoons were also shown to be processed differently by subjects with varying degrees of empathizing skills: for example, people with lower empathizing skills tend to give fewer emotional/motivational and mentalistic explanations, particularly in TOM cartoons when asked to explain why they think a cartoon is funny (Samson 2009).

The present study aims to investigate whether humor processing in individuals with AS is generally limited or whether it depends on stimuli characteristics, i.e., the LM which is the cognitive rule indicating how the incongruity of a joke has to be resolved: If humor processing is generally limited in all three groups of cartoons, this would show that individuals with AS have problems resolving the incongruity independent of the cognitive requirements that different LMs pose. This would mean that individuals with AS have a general deficit in manipulating and integrating information, which might be caused by a weak central coherence and less cognitive flexibility (Frith 1989; Frith and Happé 1994; Happé 1999). On the other hand, it is possible that individuals with AS do not have problems resolving the incongruity of PUNs, but as soon as mental states have to be attributed in order to get the joke they might have difficulties in humor comprehension. As TOM cartoons explicitly require mind-reading or mentalizing skills to be correctly understood and if the only deficit in humor appreciation is in TOM cartoons, limited mind-reading skills might be the main factor leading to humor deficits (Baron-Cohen et al. 1985; Baron-Cohen 1988; Happé 1993; Tager-Flusberg 1993).

Furthermore, it will be investigated whether the "local bias" affects humor processing: In several studies, individuals with AS were shown to focus more on details ("local bias") than on the global meaning of stimuli (e.g., Plaisted

[1] If the incongruent element of a joke is presented in the end of a verbal joke, people have to trace back to the information given in the beginning of the joke in order to reinterpret the already heard/read information in a funny way.

et al. 1998, 2003; O'Riordan 2004; Happé 1996; Bölte et al. 2007, 2008; Müller and Nussbeck 2008). This peculiarity might influence humor processing when subjects concentrate more on visual details of a cartoon without getting the global meaning of the joke. Therefore, humor processing in the present experiment is not only investigated by asking for comprehension and funniness ratings but also by taking into account explanations provided by the participants as to why they think a cartoon is funny. Explanations can illuminate the underlying cognitive processes in more detail than rating scales (e.g., Loizu 2006; Samson 2009). They can not only show whether individuals with AS focus more on (e.g., visual) details in contrast to the global meaning of the joke but also whether they refer to (false) mental states of the joke characters.

One reason why individuals with AS miss the punchline of jokes might be their reduced ability to read social cues in social interaction conditions (Baron-Cohen 1997). However, in the present approach, humor processing is investigated independently of the influence of social context and social cues: as the experiment was conducted online, subjects could participate from the comfort of their homes. Three stimulus conditions that posed different cognitive requirements were used: non-verbal, single frame cartoons that differ in their LM—PUN, SEM and TOM. Additionally, a control condition was presented that consisted of unfunny pictures containing an incongruity that could not be resolved meaningfully (INC). The comparison of INC versus the three cartoon conditions was intended to reveal the ability to discriminate unfunny from funny materials.

Furthermore, individuals with AS are described as having low empathizing abilities (attribution of mental states to others and response with an appropriate emotion) and sometimes higher systemizing abilities (comprehension for systems and its behavior Baron-Cohen 1995, 2002; Wakabayashi et al. 2007). Dziobek et al. (2008) recently showed that individuals with AS are only impaired in cognitive empathy and not in emotional empathy. However, as individuals with AS appear to score differently on empathizing and systemizing (see Baron-Cohen et al. 2003; Baron-Cohen and Wheelwright 2004; Wakabayashi et al. 2007), these scales were assessed as well in order to get additional information about the cognitive skills of individuals with AS.

Method

Participants

Individuals with AS were recruited via several clinical institutions, information and consulting centers for individuals with AS, in Germany, Austria and Switzerland. Only individuals with a confirmation (e.g., of a psychotherapist) of the diagnosis (ICD-10: F84.5) were included into the study ($N = 19$). They had an average Autism-Spectrum Quotient (AQ) of 24.11 (SD = 3.71, range from 16[2] to 30) measured with the short German version of the AQ which has a cut-off score of 17 for individuals with AS (AQ-k, Freitag et al. 2007). The control group was recruited via mailing lists at Swiss and German universities. In total, 128 subjects participated in the online study with a mean age of 25.23 years (range from 19 to 50). The 109 control participants (age $M = 24.99$, SD = 5.67) and the 19 individuals with an AS diagnosis (age $M = 27.79$, SD = 8.28) did not differ regarding their age [$F(1,127) = 3.34$, $p > .05$]. The control group consisted of 61.5% females and the AS group of 52.6%. The distribution of males and females did not differ significantly between the two groups [$\chi^2(1) = .527$, $p > .05$]. The two groups did not differ regarding their educational level: 78% of the individuals with AS and 92% of the control group were students or had a University degree [$\chi^2(1) = 2.90$, $p > .05$].

Material

Stimuli

Three types of non-verbal funny cartoons differing in their LM were used: visual puns (PUN), semantic cartoons (SEM) and Theory of Mind cartoons (TOM; see Fig. 1).

PUNs have in common, that one visual element evokes two scripts, that is, has two meanings. Therefore the incongruity-resolution is visual as well as semantic. SEMs are based on pure semantic relationships, no visual relationships are essential humor-carrying elements, and the joke can be told instead of drawn. Several LMs are subsumed in this category, for example role reversal, analogy, or exaggeration. The third stimuli group consists of cartoons where it is necessary to attribute false mental states to the characters portrayed in the cartoons. Therefore mentalizing abilities are required in order to understand the cartoon. In these TOM cartoons the incongruity-resolution is also semantic and not visual.

Furthermore, a non-funny control condition was presented containing an irresolvable incongruity (INC). These cartoons are perceived to be non-funny and have high residual incongruity (see Samson et al. 2008). This stimulus condition was used as a control for real or pretended understanding of the cartoons. In order to avoid humor fatigue effects (i.e., a decrease in the funniness response

[2] Although Freitag et al. (2007) postulated that individuals with AS score on the AQ-k at least with 17, we included one individual with AS with an AQ-k score of 16 as she had a valid diagnosis.

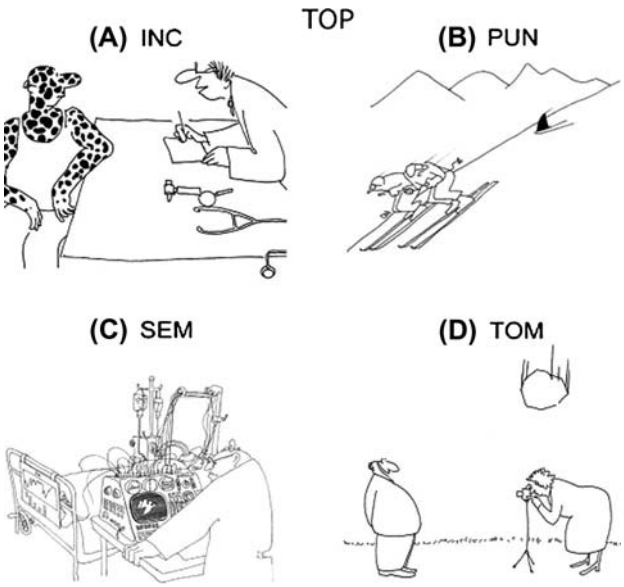

Fig. 1 Examples of the stimuli used in the study. **a** A picture containing an irresolvable incongruity (INC). **b** A visual pun (PUN): one visual element (the *diagonal line*) can stand for the sea (activated through the fin) or the mountain (activated trough the skis). **c** A semantic cartoon (SEM): the joke is based on pure semantic relations and not on visual resemblance, as in PUNs: the patient has died which can be seen on the monitor in the form of an angel flying away. There is no visual resemblance between the angel and the line which indicates no heartbeat. In order to understand the joke one does not have to refer to (false) mental states. **d** A Theory of Mind (TOM) cartoon: In order to get the joke, it is necessary to activate mentalizing abilities, namely, understand that the woman does not know what will happen to her, while the man knows what will happen. Cartoons: Copyright by Oswald Huber. Permission to use was granted

with increasing number of stimuli, see for example Forabosco 1994) eight stimuli per cartoon condition and four INCs were selected randomly out of a pool of 120 stimuli used in prior studies (e.g., Samson et al. 2008).

Questionnaires

Empathizing and Systemizing

Short German versions of the empathizing and systemizing scales (Samson and Huber 2009, which was developed on the basis of the original long versions by Baron-Cohen et al. 2003; Baron-Cohen and Wheelwright 2004) consist of 13 empathizing items (e.g., "I can easily tell if someone else is interested in or bored with what I am saying"), 13 systemizing items (e.g., "I do not enjoy games that involve a high degree of strategy") and 11 filler items. The short German version proved to be a reliable (e.g., high retest-reliability), consistent and stable instrument (see Samson and Huber 2009). The participants had to answer how strongly they agree with the statements on a 4-point scale. The answers were then recoded so that the strongest empathizing or systemizing response gets 2 points, a strong response 1 point and the two others 0 points.

Autism-Spectrum Quotient (AQ, Baron-Cohen et al. 2001)

The German short version of the AQ (AQ-k, with 33 items; Freitag et al. 2007) was used here as an additional measure to check the AS diagnosis. It is a questionnaire which covers domains connected with the autism spectrum and includes social skills, communication skills, imagination, attention to detail, and attention switching/tolerance of change. The participants had to answer how strongly they agree on a 4-point scale. One point to the overall score was given, if the answer was on the upper half of the scale. The AQ-k showed a good discriminative validity and good screening properties at a cut-off score of 17 for individuals with AS (Freitag et al. 2007).

Procedure

First, several clinical institutions in Germany, Austria and Switzerland and information and consulting centers were contacted to recruit individuals with AS. The control group was recruited via mailing lists at Swiss and German universities. People interested in taking part in the study were invited to write an email to us in order to get an individual password to have access to the online humor experiment. Once logged in, they received instructions to rate each cartoon for comprehension (yes/no), for funniness on a 6-point scale (from 0 to 5) and to explain in writing why they thought a cartoon is funny or to explain the punchline. Before the humor experiment started, they were asked to fill in the short German version of the empathizing and systemizing questionnaire (Samson and Huber 2009). Subsequently 29 stimuli (24 funny cartoons and four control stimuli and one warm-up) were presented in random order. At the end of the experiment, the participants had to indicate whether they had been diagnosed as having AS. Furthermore, they were asked to indicate where and by whom they were diagnosed. After this procedure, the individuals with AS were invited to fill in the AQ-k online.

Results

Thirty-two individuals indicated they had an AS diagnosis, however, only those were included in the analysis for whom (1) there was obtained an official confirmation of the AS diagnosis (ICD-10: F84.5, e.g., by a psychiatrist), and (2) AQ-k scores ($N = 19$) were available. Individuals with AS had significantly lower empathizing [$F(1, 127) = 60.51$, $p < .001$] and higher systemizing scores [$F(1, 127) = 11.52$, $p < .001$] than the control group (see Table 1) which

Table 1 Mean empathizing and systemizing scores for the individuals with AS and the control group

	Controls ($N = 109$)	AS ($N = 19$)
Empathizing (M, SD)	13.40 (5.45)	3.37 (3.20)
Systemizing (M, SD)	8.76 (4.92)	12.89 (4.76)

is in line with Baron-Cohen et al. (2003) and Baron-Cohen and Wheelwright (2004). The two scales correlate negatively [$r(128) = -.25$, $p < .01$] if all participants (individuals with AS and control group) were included due to the typical pattern of low empathizing and (commonly) higher systemizing scores in individuals with AS. Considering only the control sample, empathizing and systemizing did not correlate significantly [$r(109) = -.09$, $p = .37$] which is to be expected as they are described as to be independent psychological dimensions by Baron-Cohen (2002) and Baron-Cohen and colleagues (2003, 2004; see Table 1).

Humor Ratings

In the next step, comprehension and funniness ratings were analyzed by means of 2 × 4 repeated measure ANOVAs with AS versus control group as a between-subjects factor and the four stimulus conditions as a within-subjects factor, followed by Bonferroni-adjusted single comparisons. Gender was included as a covariate. If the Mauchly's test of sphericity did not show equality of the variances, a Greenhouse Geisser correction was applied.

Comprehension

First, we compared comprehension ratings for the three cartoon conditions and the control condition items (pictures containing an irresolvable incongruity, INC). Therefore, the mean comprehension ratings for the INC condition, as well as for each of the humor condition were computed. The INC condition had the lowest comprehension ratings, followed by PUNs, SEMs and TOMs (see Table 2).

Table 2 Means and standard deviations for comprehension and funniness ratings of individuals with AS ($N = 19$) and the control group ($N = 109$) for PUN, SEM and TOM cartoons and the control condition (INC)

	INC M (SD)	PUN M (SD)	SEM M (SD)	TOM M (SD)
Comprehension				
Controls	.41 (.27)	.69 (.23)	.82 (.17)	.83 (.19)
AS	.26 (.21)	.48 (.22)	.69 (.23)	.68 (.22)
Funniness				
Controls	1.70 (.83)	3.52 (.94)	4.10 (.97)	4.34 (.95)
AS	1.76 (1.03)	3.08 (1.31)	3.19 1.13)	3.36 (1.23)

A repeated measure analysis showed a significant main effect for the stimulus conditions (Mauchly's $W = .61$, $\chi^2(5) = 61.90$, $p < .001$; Greenhouse Geisser $F(2.23, 278.11) = 16.35$, $p < .001$). Single comparisons revealed that all stimulus conditions differed significantly from each other ($p < .001$), except for the SEM and TOM condition. Neither the interaction of stimulus conditions and groups (controls vs. individuals with AS) nor the interaction of stimulus conditions with gender was significant. Over all four stimulus conditions, individuals with AS had lower comprehension ratings [$F(1, 126) = 16.17$, $p < .001$], indicating that individuals with AS understood all humor conditions less well than the control group. Also gender showed a significant effect in the between-subjects effects [$F(1, 126) = 9.48$, $p < .01$], indicating that females had slightly lower comprehension ratings than males. However, the effect of AS versus the control group was stronger than the effect of gender. Although the control condition items (irresolvable incongruities) were not intended to be funny (pre-examinations showed that they were not perceived to be funny, see Samson et al. 2008), participants sometimes rated the cartoons as understood, although they were not intended to be rated as jokes. Reasons for rating these control cartoons as understood, could have arisen as participants were informed that the experiment was a study of humor (so the participants assumed that they were supposed to find a punchline and judged the irresolvable incongruities as jokes) as well as social desirability (sense of humor is generally perceived to be a socially desirable personality characteristic, see Martin 2006). However, this poses no problem for the further analyses on humor appreciation, since only the understood cartoons and non-understood control stimuli were taken into account.

In order to analyze whether individuals with AS discriminate between funny materials and the pictures containing irresolvable incongruities, the mean comprehension scores of the control condition were subtracted from the mean comprehension score of all funny cartoons. Individuals with AS ($M = .36$, SD = .27) did not differ significantly from the control group ($M = .37$, SD = .27, $F(1, 127) = .06$, $p = .80$) which suggests that individuals with AS have no general difficulties discriminating funny stimuli from unfunny stimuli (i.e., independent of a social context).

Funniness

For the analysis of humor appreciation, the mean funniness ratings of the non-understood control condition (INC) as well as of the understood cartoons were computed (see Table 2). A 2 × 4 repeated measure analysis with gender as covariate revealed a significant main effect for the stimulus conditions (Mauchly's $W = .79$, $\chi^2(5) = 26.15$, $p < .001$; Greenhouse Geisser [$F(2.61, 303.18] = 13.31$,

$p < .001$). Funniness scores were lowest for the INC condition and higher for PUN, to SEM, to TOM, in that order. Funniness ratings differed significantly between all stimulus conditions ($p < .001$, Bonferroni-corrected), except for the comparison between SEM and TOM cartoons for which there was no significant difference. Furthermore, the interaction of the stimulus conditions and groups (controls vs. individuals with AS) was significant [Greenhouse Geisser ($F(2.61, 303.18) = 7.68$, $p < .001$)]. One-way ANOVA's yielded no significant differences in the INC and PUN condition between individuals with AS and the controls. However, the control group rated SEM [$F(1, 126) = 10.76$, $p < .01$] and TOM cartoons [$F(1, 126) = 13.57$, $p < .001$] as significantly funnier than individuals with AS. Over all four stimulus conditions, individuals with AS had significantly lower funniness ratings [$F(1, 116) = 7.89$, $p < .01$]. The interaction of stimulus conditions with gender was not significant and males and females did not differ in their funniness ratings over all stimulus conditions.

Subsequently, it was of interest whether the individuals with AS did profit from additional social cues, which are more prominent in SEMs in contrast to PUNs and most prominent in TOMs, as the punchlines in TOM cartoons are based on false mental states. In the control group, the funniness ratings were greater in SEM cartoons, compared to PUN cartoons [$t(107) = 7.00$, $p < .001$] but not for individuals with AS [$t(18) = .54$, $p = .60$]. The same was observed for the comparison between SEM and TOM cartoons: in the control group, funniness ratings increased if the punchline was based on false mental states [$t(106) = 3.57$, $p < .001$] but not in individuals with AS [$t(18) = .80$, $p = .44$]. Therefore, individuals with AS perceive all three humorous cartoon conditions on the same level of funniness. This indicates that they do not profit from social cues and jokes about false mental states, which were described in previous studies as funniness enhancing factors (Samson et al. 2008).

Humor Explanations

The explanations and comments given by each participant were analyzed qualitatively: The explanations were rated for whether someone referred to details that were irrelevant for the humor of the cartoon and whether mentalistic explanations were given.

Coding Procedure

The explanations of the PUN, SEM and TOM cartoons (24 per participant) were coded binomially (yes/no) for the two following criteria: *Detail orientation*: It was coded whether the focus of the explanation was on features of the cartoon that are not joke relevant, for example that "…a runway was too short for an airplane to take off …" or that "…a wall could not stand because of the lack of a base…". *Mentalistic explanation:* In order to get a score here, participants had to refer to false mental states, e.g., to a false belief of a character portrayed in the cartoon (e.g., "…person X does not know what person Y is doing behind his back…"). As it might be possible for participants to give a wrong mentalistic explanation, it was coded independently from the correctness of the explanation whether participants referred to false mental states at all.

To compute inter-rater reliability for detail orientation and mentalistic explanations, two cartoons per condition (i.e., in total 870 explanations, which is 30% of the total of 2,856 explanations) were randomly selected and coded by a second rater. In the coding procedure, the two coders did not know whether the participants were individuals with AS or part of the control group. Inter-rater reliability was satisfactorily high for detail oriented explanations in general (*Kappa* = .80), PUNs (*Kappa* = .83), SEM (*Kappa* = .74) and TOM cartoons (*Kappa* = .86). The same holds for mentalistic explanations in general (*Kappa* = .92), PUN (*Kappa* = .73), SEM (*Kappa* = .86) and TOM cartoons (*Kappa* = .94; usually, a *Kappa* of .70 is considered as very satisfactory).

Detail Orientation

For each individual, the number of the detail-oriented explanations was summarized per each cartoon group. A 2×3 repeated measure analysis with the three cartoon conditions as within-subject variable, groups (controls vs. individuals with AS) as between-subjects variable and gender as covariate revealed no significant main effect for the stimulus conditions. Neither the interaction of the stimuli conditions and groups (controls vs. individuals with AS) nor the interaction with gender was significant. Over all cartoon conditions, individuals with AS referred significantly more often to non-joke relevant details [$F(1, 125) = 31.40$, $p < .001$], indicating that in each cartoon condition, individuals with AS gave more detail-oriented explanations than the control group. However, there was no effect of gender over all cartoon conditions. For means and standard deviations see Table 3.

Mentalistic Explanations

For each individual, the number of the mentalistic explanations was summarized for each cartoon group. A 2×3 repeated measures analysis with the stimulus conditions as within-subject variable, groups (controls vs. individuals with AS) as between-subjects variable and gender as covariate revealed a significant main effect for the cartoon

Table 3 Means and standard deviations for detail orientation and reference to false mentalistic states in the explanations of individuals with AS ($N = 19$) and the control group ($N = 109$) for PUN, SEM and TOM cartoons

	PUN *M* (SD)	SEM *M* (SD)	TOM *M* (SD)
Detail orientation			
Controls	.33 (.67)	.30 (.71)	.20 (.49)
AS	1.00 (.88)	1.16 (1.12)	1.00 (1.33)
Mentalistic explanations			
Controls	.18 (.41)	.23 (.53)	3.07 (1.96)
AS	.00 (.00)	.05 (.23)	1.68 (1.38)

conditions (Mauchly's $W = .27$, $\chi^2(2) = 165.49$, $p < .001$; Greenhouse Geisser [$F(1.15, 144.08) = 13.55$, $p < .001$]. Single comparisons revealed that in TOM cartoons more mentalistic explanations were given than in PUN cartoons [$t(127) = 16.22$, $p < .001$] or in SEM cartoons [$t(127) = 16.17$, $p < .001$], whereas PUN and SEM did not differ significantly from each other in the number of mentalistic explanations provided. The interaction of the three cartoon conditions and groups (controls vs. individuals with AS) was significant [Greenhouse Geisser ($F(1.15, 144.08) = 6.513$, $p < .01$)] but the interaction of stimulus conditions with gender was not significant. Over all three cartoon conditions, individuals with AS gave significantly fewer mentalistic explanations [$F(1, 125) = 10.05$, $p < .01$]. This is mainly due to the difference in the TOM condition as individuals with AS and the controls did not differ in the PUN and SEM condition. The main finding here is that the control group gave significantly more mentalistic explanations in TOM cartoons than individuals with AS [$F(1, 127) = 8.791$, $p < .01$]. There was no effect of gender over all cartoon conditions.

Discussion

The results of the present study show that individuals with AS have more difficulties than the control group in comprehending humorous material (i.e., cognitive humor processing), independent of the LM. However, as the proportion of understood cartoons to non-understood pictures containing an irresolvable incongruity did not differ between individuals with AS and controls, it can be concluded that the ability to discriminate unfunny from funny materials does not differ between the two groups. Furthermore, individuals with AS rate SEM and TOM cartoons as significantly less funny than controls which indicates reduced affective humor processing. While there was an increase in funniness ratings from PUN to SEM to TOM due to a profit from social cues as funniness enhancers in the control group, this increase was not found in individuals with AS, which means that they do not benefit from additional social aspects as funniness enhancing factors, such as taking into account mental states and attributing false mental states (Samson et al. 2008). This was also shown by taking the explanations into account: Whereas TOM cartoons provoked more mentalistic explanations in contrast to PUN and SEM cartoons, individuals with AS referred less frequently to false mental states, in particular in the TOM condition and never in the PUN condition. Interestingly, even in the PUN condition, controls spontaneously referred to false mental states, although this was not required in order to get the joke. Furthermore, significant differences between individuals with AS and controls were found regarding the attention to detail in their explanations: Independent of the LM, individuals with AS more often focused on non-joke relevant details indicating that independent of the stimulus characteristics, individuals with AS process humorous stimuli differently.

The finding that individuals with AS show overall lower comprehension ratings might support the view of Emerich et al. (2003) that weak central coherence and less cognitive flexibility influence humor processing in individuals with AS. Also, their focus on visual details is supporting this view. This is in line with the generally good performance in visual search described in the literature (e.g., Bölte et al. 2008). However, it is not clear whether such a detail oriented processing style leads to a failure in understanding the global meaning of the joke or whether individuals with AS are even amused by such detail focused explanations. A reanalysis of the detail-oriented explanations of the individuals with AS (in total 111 explanations) showed that both is possible: Across the 24 cartoons, individuals with AS indicated more frequently that they understood the cartoon ($M = 2.92$, SD = 1.67) in contrast to that they did not understand the cartoon ($M = 1.67$, SD = 1.63; $t(23) = 2.363$, $p < .05$), which shows that they are sometimes amused about such detail-focused explanations or that they refer to them additionally. However, in some cases it was clear that the focus on details leads to a failure in getting the joke (e.g., "…if this object is moving on the water, there is a lack of waves indicating this movement…, however, I don't get it"). Abstractions and simplifications in the drawing style such as, for example, omitting visual details (e.g., waves on the water indicating movement) or simple lines instead of detailed and realistic drawings are typical for visual humor and are usually not part of further conscious considerations in normally developing individuals. Furthermore, it was striking how often the detail oriented-explanations of individuals with AS were accompanied by statements that a certain situation is just "not possible" or "not realistic". This seems to indicate a problem with switching from a bona-fide reality-based mode to a non-bona-fide joke mode. Particularly in cartoons, many aspects

are present that are not realistic (e.g., speaking animals) or drawn in an abstract (unrealistic) style and require a momentary, partial suspension of disbelief. The ability to do this switch is part of normal communicative competence and normally developing individuals do not refer to the physical impossibility of a wall that can not stand without its base, for example, when the level of detail in a cartoon does not require the explicit incorporation of such a base. We assume that individuals with AS are less able to suspend disbelief in a humorous context and that they are more reality-oriented. However, this assumption as well as the relationship of humor appreciation and the detail-oriented processing style needs to be investigated further.

This study shows not only that a weak central coherence, less cognitive flexibility and a local bias might be responsible for certain deficits in humor processing, but also that social cognitive deficits, such as the inability to read minds, lead to a different pattern in humor processing: individuals with AS did not profit from social involvement as a factor increasing the perceived funniness (Samson et al. 2008), but rated PUN, SEM and TOM on the same funniness level. The often postulated influence of limited mind-reading skills on humor processing in individuals with AS is also attested by the circumstance that they referred less often to false mental states of the characters portrayed, particularly in TOM cartoons.

As PUN, SEM and TOM cartoons require different cognitive processes to be understood (see Samson et al. 2008) and as they were processed differently by individuals with AS from those in the control group, we suggest that differences between the studies on humor in individuals with AS are, inter alia, due to differences in the stimulus material. As a key result of the present study, we recommend controlling stimuli for their cognitive requirements in more detail for future studies.

The lower comprehension and funniness ratings raise the question whether this response behavior might be traced back to less socially desirable answer tendencies in individuals with AS (a social desirable answer would be to find the jokes funny and comprehend them in order to seem not humorless). Although we cannot exclude this possibility, a recent study showed that individuals with AS performed at a comparable level to controls on a social desirability scale (Dziobek et al. 2008). Furthermore, it is not likely that individuals with AS who participated in this study were less motivated than the control group to fill in the online questionnaires and to rate the cartoons.

Some limitations of the present study have to be mentioned. For example, the male–female ratio of the AS group is not representative of what would be found in a true community sample. Although gender revealed to have only an overall effect on comprehensibility which was weaker than the difference between individuals with AS and the control group, it cannot be excluded that—if more male individuals with AS would have participated in the experiment—the differences found would have been even more pronounced. A further point is that the data were collected online: although Internet-based studies are usually equally reliable and valid as paper–pencil based methods (more traditional strategies) and samples collected via the Internet usually show more diversity than other samples (e.g., Gosling et al. 2004, see also Birnbaum 2000), this procedure does not allow to collect additional data, for example, on facial expressions. Furthermore, it was not asked for other parameters such as the IQ or psychiatric disorders other than AS. Future studies should pay more attention to factors that might influence humor processing in general as well as differences between the control group and individuals with AS.

To conclude, we assume that the reduced humor appreciation in individuals with AS depends on the cognitive requirements that the stimuli pose on the perceiver, since they do not differ in the funniness rating in the PUN condition. However, whereas controls profit from social funniness-enhancing factors in the SEM and TOM condition, individuals with AS do not. Their enjoyment remains on the same level in all three stimulus conditions. This means that they show less emotional responsiveness towards potentially-funny stimuli where social cognition (such as ascribing false mental states) is involved. This is in line with the findings of Baron-Cohen (1988, 1997); Baron-Cohen et al. (1985); Happé (1993) or Tager-Flusberg (1993). Furthermore, the lower cognitive flexibility (Frith 1989; Frith and Happé 1994; Happé 1999) leads to lower comprehension in general. Another key result is that individuals with AS more often show a focus on non-humor relevant details than the controls. This detail-oriented processing style sometimes leads to the failure in getting the joke. However, from our data it can be suggested that as a consequence of this processing style, other aspects of the humorous stimuli lead to amusement than in normally developed individuals. Additionally, it is possible that individuals with AS possess a more reality based processing style (bona-fide reality-based). This processing style might lead to less humor enjoyment as well. This opens a variety of new research questions, for example, what leads to this more reality oriented processing style and whether other domains than humor are affected as well.

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