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## Empathic resonance in Asperger syndrome

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## ABSTRACT

Reports on theory-of-mind deficits have led to the common belief that autism spectrum disorders (ASD) are associated with a lack of empathy. Resonance is a basic empathy-related process, linking two interacting individuals at the physiological level. Findings in ASD have been inconclusive regarding basic empathy. We investigated resonance at the autonomic level – the salivation-inducing effect of watching a person eating a lemon. Salivation-induction was assessed in 29 individuals with ASD and 28 control participants. Cotton rolls placed in the mouth were weighed before and after the video stimulation. Orientation to the stimulus was assessed with eye-tracking, autistic and empathic traits through self-reports. Group comparisons revealed lower salivation-induction in individuals with ASD. Linear regressions revealed different predictors of induction in each group: self-reported empathic fantasizing and age in ASD versus self-reported empathic concern plus orientation to the stimulus' face in the control. In both groups the social component was relevant: in ASD in terms of intellectual involvement with social contents and in controls in terms of the mere presence of a social vis-à-vis. Individuals with ASD may use explicitly acquired intellectual strategies whereas individuals with typical development can rely on intuitive processes for social responsivity.

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## 1. Introduction

Autism spectrum disorders (ASD) are associated with generally reduced social–emotional reciprocity and empathy. However, various definitions of empathy have caused researchers to adopt several methods for assessing this complex process. Within the context of ASD, one of the most popular concepts for study has been that of cognitive empathy, i.e., perspective-taking or Theory of Mind (ToM). Deficits in those processes have been replicated numerous times in individuals with ASD. Nevertheless, criticism has emerged about the explanatory power of ToM because of its lack of specificity to autism and its strong relationship with language abilities (Happé & Frith, 1996; Klin, Jones, Schultz, Volkmar, & Cohen, 2002a; Senju, 2013). For example, compensation strategies by persons with ASD, e.g., heightened verbal skills, can lead to discrepancies between having good results in explicit tasks of social reasoning and dealing with real-life difficulties (Klin, Jones, Schultz, & Volkmar, 2003; Klin et al., 2002a; Senju, 2013).

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Empathy is influenced by many conscious and unconscious factors that can be difficult to control in an experimental setting. Current means for assessing empathic abilities in ASD may benefit from an approach that examines more basic processes related to empathy within a broader framework of empathy. The perception-action link (Preston & de Waal, 2002) describes empathy-related, automatic processes that occur when two people are interacting. The perception of someone's action automatically stimulates the observer's corresponding representations, so that one involuntarily and directly matches the physiological state of the other person. Unless inhibited, those shared representations then prime or generate an associated action in response that depends upon the level of attention to the stimulus (Preston & de Waal, 2002). This physiological linkage between two individuals, i.e., resonance, is a basic way of being in social contact, and was proposed to be related to empathy (Gonzalez-Liencres, Shamay-Tsoory, & Brüne, 2013; Haker, Schimansky, & Rössler, 2010; Levenson & Ruef, 1992). Common measures of empathic resonance are spontaneous imitation or mimicry of facial expressions (Cacioppo, Petty, Losch, & Kim, 1986), or contagion effects such as in yawning (Norscia & Palagi, 2011; Platek, Critton, Myers, & Gallup, 2003), laughing (Provine, 2005), or itching (Papoiu, Wang, Coghill, Chan, & Yosipovitch, 2011).

Comparison among results from previous reports about resonance in ASD is challenging due to the high heterogeneity in such spectrum disorders and in the different studied groups. Those differences have been manifested in terms of age, intellectual level, or personality traits such as alexithymia, a sub-clinical, frequently co-occurring phenomenon characterized by difficulties in identifying and describing one's own feelings (Nemiah, 1977). Even though those previous examinations had an advantage because they relied less on verbal skills by the participants than do explicit tasks (e.g., ToM), the results were sometimes inconsistent. For example, during passive viewing, children with ASD did not mimic until instructed to do so, suggesting that spontaneous mimicry is impaired in those disorders (McIntosh, Reichmann-Decker, Winkelman, & Wilbarger, 2006). However, other studies reported intact spontaneous mimicry in ASD (Magnee, de Gelder, van Engeland, & Kemner, 2007; Press, Richardson, & Bird, 2010). Those examples highlight important aspects when applying experimental paradigms in individuals with ASD. Differences in task instructions – maybe even subtle – can lead to contrasting responses by participants. In addition, due to their qualitatively different, e.g., literal, understanding, individuals with ASD may obtain a different meaning for a task instruction than do control participants. This risk increases with the complexity of actions a participant is required to perform. Furthermore, the observed response may cognitively be influenced by the participants themselves, perhaps unintentionally through education or social desirability, or intentionally through manipulation.

In studies of contagious yawning, children with ASD did not yawn when they observed a yawning person in a video, in contrast to typically developing children (Senju et al., 2007). However in a replication study, when the children were instructed to look at the eyes of the stimulus this group difference disappeared (Senju et al., 2009). In accordance with those findings, researchers have suggested that an atypical orientation to the stimulus might be responsible for inconsistent results (Klin, Jones, Schultz, Volkmar, & Cohen, 2002b; Senju, 2013). Several investigations utilizing eye-tracking methodology have shown that visual strategies vary between ASD individuals and persons in the control groups. In contrast to typically developing individuals, children and adults with ASD show preferential attention to inanimate rather than social stimuli (Klin et al., 2002b). They also focus less consistently on core features of the human face, such as the eyes and mouth (Langdell, 1978). However, empathic processes can also be disrupted by cognitive load in non-autistic individuals, indicating that attention impacts empathic processing (Morelli & Lieberman, 2013). Preston and de Waal (2002) have also conceptualized attention as a key component of the perception-action link. Therefore, the impact of atypical attention paid to a stimulus (e.g., in terms of the atypical visual orientation found in ASD) on the empathic response seems obvious.

Here, we assessed basic empathic resonance with the salivation test, a paradigm that minimizes the above-mentioned influences of instruction and participants' cognition (Hagemuller et al., submitted). This test evaluates the salivation-inducing effect of watching a person eating a lemon. Instruction is minimal, the participants are not required to take a specific action, and the cognitive influence that participants could have on their own salivation rates is comparably low. To understand better the underlying mechanisms, we also assessed spontaneous visual orientation via eye-tracking. Our aim was to investigate a basic empathic process described by the perception-action link in adults with ASD who had no intellectual disability. We predicted that the empathic response would depend upon the degree of visual attention paid to the stimulus as well as personality characteristics.

## 2. Method

### 2.1. Participants

Our assessment involved 29 participants with Asperger syndrome (AS group, mean age 35 years, age range 18–59 years, 11 females) plus 28 control participants (control group, CG, mean age 33 years, age range 21–57 years, 11 females) of a similar age and gender distribution. The participants of the CG had no psychiatric history and were free of pharmacological medication. They were part of a larger group of control participants described previously (Hagemuller et al., submitted). Participants in the AS group had been diagnosed by senior mental-health professionals experienced in those disorders following the criteria of DSM-IV. The standard diagnostic procedure included a minimum of 6 h of exploration (in multiple sessions) with a focus on autistic symptomatology and developmental history, and a collateral history taking. The diagnosis was only given, if a second professional experienced in autism spectrum disorders confirmed the evaluation based on a summary of this information and her presence in one of the exploration sessions. Standardized clinical instruments, such as

ADI-R (Lord, Rutter, & Le Couteur, 1994) or ADOS (Lord et al., 2000), were not used because their clinical validity (e.g., sensitivity) is not well-documented for the diagnostic identification of adults at the higher-functioning end of the autism spectrum. However, only the enrollment of higher-functioning, less severely impaired participants allows one to investigate underlying coping strategies.

In the AS group, 10 participants were medicated with antidepressants, two with antipsychotics, one with both, and one with both plus antiepileptics and methylphenidate. Intellectual abilities were estimated with two tests of the Wechsler Adult Intelligence Scale (WAIS-III) – Block Design for performance IQ and Arithmetic for verbal IQ (Wechsler, 1981). These two tests were selected as two out of four (for administration time reasons) that were recommended as estimators for the full scale by Doppelt (1956). None of the participants had an intellectual disability. Persons in the AS group scored significantly higher ( $M = 108$ ,  $SD = 10$ ) than those in the CG ( $M = 100$ ,  $SD = 11$ ) on verbal IQ tests,  $t(55) = 2.76$ ,  $p = .008$ .

Participants were instructed not to eat anything, drink coffee, brush teeth, or chew gum for half an hour prior to the experiment. After complete description of the study to the subjects, written informed consent was obtained. The study was approved by the regional ethics committee of Zurich.

## 2.2. Salivation-induction

With three cotton dental rolls placed in their mouths (two buccally and one on the tongue), the participants watched videos. The rolls were weighed before and after the video was presented to determine how much saliva had been absorbed in order to assess salivation-induction (balance with weighing range 100 g, graduation 0.01 g).

The stimulation video showed a person cutting and eating a lemon. The control video represented the same person retrieving paper balls of different colors and placing them before him on the table. This version was used as the control to establish baseline salivary flow. Each 60-s video was displayed three times in randomized order. Recovery periods between videos lasted at least 10 min. The instruction for the lemon video was “watch the video” whereas the instruction for the control video was “count the paper balls” (a different color for each of the three runs). This control task was very easy and was aimed at activating representations other than food, sourness, or anything else associated with eating lemons. The level of salivation induction was calculated as the difference between mean salivation under the lemon condition and mean salivation in the control situation. This test has been developed previously (Hagemuller et al, submitted).

## 2.3. Gaze behavior

A table-mounted Eyegaze Analysis System (LC Technologies, Inc.) was used to measure eye movements. The individual was seated approximately 60 cm in front of a 19" LCD Monitor, his or her eyes leveled with the upper half of the screen. The head was placed on a chinrest to ensure a neat calibration. For each participant, a nine-point calibration of the eye-tracker, made before the salivation test started, was adjusted before each run. Eye movements were recorded binocularly (sampling rate of 120 Hz) by two cameras positioned beneath the computer display with the pupil center corneal reflection method. For two participants, eye-tracking was assessed only with the dominant eye because of calibration problems due to reflection from their glasses. In both test groups, the right eye was dominant for half of the participants; the left for the other half. Because of a strong strabismus, the eye-tracking data for one participant in the AS group had to be excluded from the analysis. We used NYAN 2.0 software (Interactive Minds, Dresden) for recording and analyzing participants' eye movements (minimum fixation duration: 50 ms).

Analyses of gaze behavior were performed for the lemon video. To disentangle attention to the social part of the stimulus from the inanimate part, we defined the following areas of interest (AOIs): (a) AOI\_face from the moment the person in the video is biting in the lemon, i.e., 18.0 s after stimulus onset; (b) AOI\_lemons; (c) AOI\_out (Fig. 1). The following AOI metrics were separately calculated: time to first fixation (in s), defined as the start time of the first fixation in a given AOI with respect

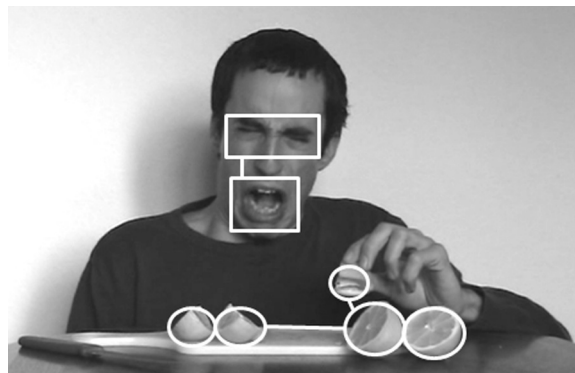


Fig. 1. Illustration of defined AOIs in the lemon video for salivation test: AOI\_face (grouping AOI\_mouth and AOI\_eyes), AOI\_lemons (grouping of all lemons), and AOI\_out as remaining unmarked area.

to the stimulus onset time; mean fixation duration (s), defined as the average of the durations of fixations within a given AOI; and gaze duration (s), defined as the sum of all fixation durations for a given AOI.

#### 2.4. Personality

Prior to the experiment, participants completed questionnaires assessing personality traits. The Autism-Spectrum Quotient (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) entailed 50 questions to assess the extent to which individuals expressed traits associated with the autism spectrum.

The Toronto Alexithymia scale (TAS) is a self-report questionnaire (Bagby, Parker, & Taylor, 1994a) that measures a participant's ability to recognize and verbally express his feelings, as well as the tendency to focus on superficial events rather than thinking about emotions. This scale has good internal consistency and test-retest reliability (Bagby, Taylor, & Parker, 1994b).

The Interpersonal Reactivity Index (IRI) uses four scales for self-reported measurements of empathy (Davis, 1980). The 'empathic concern' (IRI\_EC) scale addresses the respondents' capacity for concerned and compassionate feelings for others; 'personal distress' (IRI\_PD) assesses self-oriented responses to difficult situations of others; 'perspective-taking' (IRI\_PT) focuses on mentalizing abilities, i.e., the ability to adopt another's point of view; and the 'fantasy scale' (IRI\_FS) measures the tendency to identify with fictional characters, e.g., in books or movies. These four scales demonstrate good internal consistency and test-retest reliabilities (Davis, 1983).

#### 2.5. Statistical analysis

Datasets were restructured with MATLAB R2012b (MathWorks) and then exported to SPSS. All statistical analyses were performed with IBM SPSS Statistics 20, using two-tailed  $p$ -values. The data were normally distributed.  $T$ -tests were performed to detect group differences in salivation, personality, and AOI-metrics.

First, the distribution of both sexes was equal between but not within the groups, and sex differences might be present in tasks within the social domain (Eisenberg & Lennon, 1983; McLennan, Lord, & Schopler, 1993). Second, salivation changes with aging (Nirenberg & Miller, 1982). These variables were therefore entered as covariates into an ANCOVA. Correlations were computed with Pearson's  $r$  in the two separated groups. The sizes of the effects were reported as Cohen's  $d$ - and  $r$ -values (benchmarks are as follows:  $d = 0.3$  respectively  $r = .1$  depicts a small effect;  $d = 0.5$  resp.  $r = .3$  a medium effect;  $d = 0.8$  resp.  $r = .5$  a large effect). Linear regressions of the outcome variable 'salivation' on the variables of interest were performed separately for both groups in order to identify possible predictors specifically related to ASD.

### 3. Results

#### 3.1. Group comparisons

On average, induced salivation was slightly lower in the AS group than in the CG. However, variances were similar in both groups. Nineteen participants from the AS group and 24 from the CG demonstrated induction, i.e., producing a value above zero (Fig. 2A). To control for Sex and Age, we calculated group differences with an ANCOVA. The covariate 'Age' was significantly related to the participant's level of salivation,  $F(1,52) = 7.11$ ,  $p = .01$ ,  $r = .35$ . We also found a significant main effect of Group after controlling for the effect of participant's Age,  $F(1,52) = 5.02$ ,  $p = .03$ ,  $r = .24$ . Neither the main effect of Sex nor the interaction effect of Group X Sex was significant ( $p = .97$ ). In the AS group, no significant difference in salivation was detected between medicated and non-medicated subjects (antidepressants and antipsychotics),  $t(27) = 1.41$ ,  $p = .17$ .

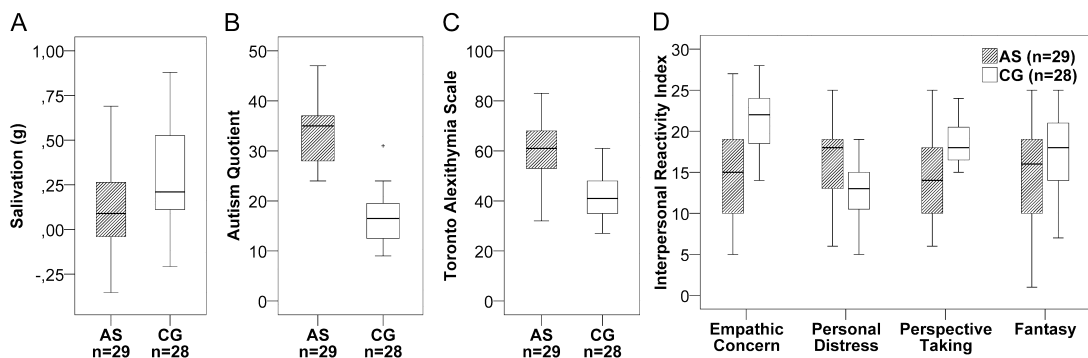


Fig. 2. Boxplots of differences between the Asperger syndrome (AS) and the control (CG) groups in salivation (panel A), autistic traits (panel B), alexithymia (panel C), and empathic abilities (panel D).

**Table 1**  
AOI metrics for the participants in the Asperger syndrome (AS) and the control (CG) groups.

AOI metrics	AS		CG		<i>p</i>	<i>d</i>
	Mean	SD	Mean	SD		
Gaze duration (s)						
AOL_face <sup>a</sup>	21.1	8.0	27.8	4.9	<.001	–1.03
AOL_lemons	14.7	8.0	10.6	3.7	.02	0.79
AOL_out	10.1	5.7	5.5	3.7	<.001	0.99
Time to first fixation (s)						
AOL_face	19.6	1.4	19.0	0.7	.08	
AOL_lemons	2.3	3.6	2.2	4.0	.91	
AOL_out	1.7	2.3	2.2	2.4	.46	
Mean fixation duration (s)						
AOL_face	0.7	0.2	0.6	0.3	.38	
AOL_lemons	0.5	0.1	0.5	0.1	.70	
AOL_out	0.4	0.2	0.3	0.1	.12	

<sup>a</sup> AOL\_face includes both AOL\_eyes and AOL\_mouth; timing began 18.0 s after stimulus onset.

Metrics for AOL\_face, AOL\_lemons, and AOL\_out are given in Table 1. On average, persons in the AS group looked significantly less at the face of the stimulus when compared with those in the control group. By contrast, the AS group participants looked significantly more at the lemons as well as outside of the AOIs. No significant group differences were found between time to first fixation and mean fixation durations. Separate analyses of both parts of the AOL\_face, i.e., AOL\_eyes and AOL\_mouth, revealed no group differences in gaze durations, time to first fixation and mean fixation durations.

The groups differed significantly in autistic personality traits. Persons in the AS group showed higher AQ values [ $t(55) = 10.98, p < .001, d = 2.96$ ]. Except for one control subject, the distributions did not overlap (Fig. 2B). On the alexithymia scale, the AS group scored significantly higher than the control group [ $t(55) = 6.24, p < .001, d = 1.68$ ] (Fig. 2C).

Comparisons on the IRI scales indicated significantly lower scores for the AS group on both empathic concern [ $t(55) = -4.80, p < .001, d = -1.29$ ] and perspective-taking [ $t(55) = -2.86, p = .006, d = -2.86$ ]. The AS group scored significantly higher on the personal distress scale [ $t(55) = 2.73, p = .008, d = .73$ ]. The groups did not differ significantly on the fantasy scale [ $t(55) = -1.38, p = .17$ ] (Fig. 2D). Variances within the AS group were higher for all four subscales.

### 3.2. Relationships among salivation, gaze behavior, and personality traits

Correlations of salivation-induction with gaze orientation and personality characteristics are shown in Fig. 3. They include *r*-values for effect-sizes and levels of significances.

Participants who looked longer at the face of the person biting in the lemon showed greater induction of salivation (Fig. 3A). In the AS group, those who gazed longer at the lemons showed less induction (Fig. 3B). The correlation of salivation with AOL\_out had a small effect-size and was not significant (AS:  $r = .15$ , CG:  $r = -.18$ ).

Participants reporting more 'empathic concern' (Fig. 3C) and more 'fantasy' (Fig. 3D) than others had more salivation-induction. Those with fewer autistic traits (Fig. 3E) and less alexithymia (Fig. 3F) also had greater induction. No correlation was found between salivation and the IRI scales 'perspective-taking' and 'personal distress'.

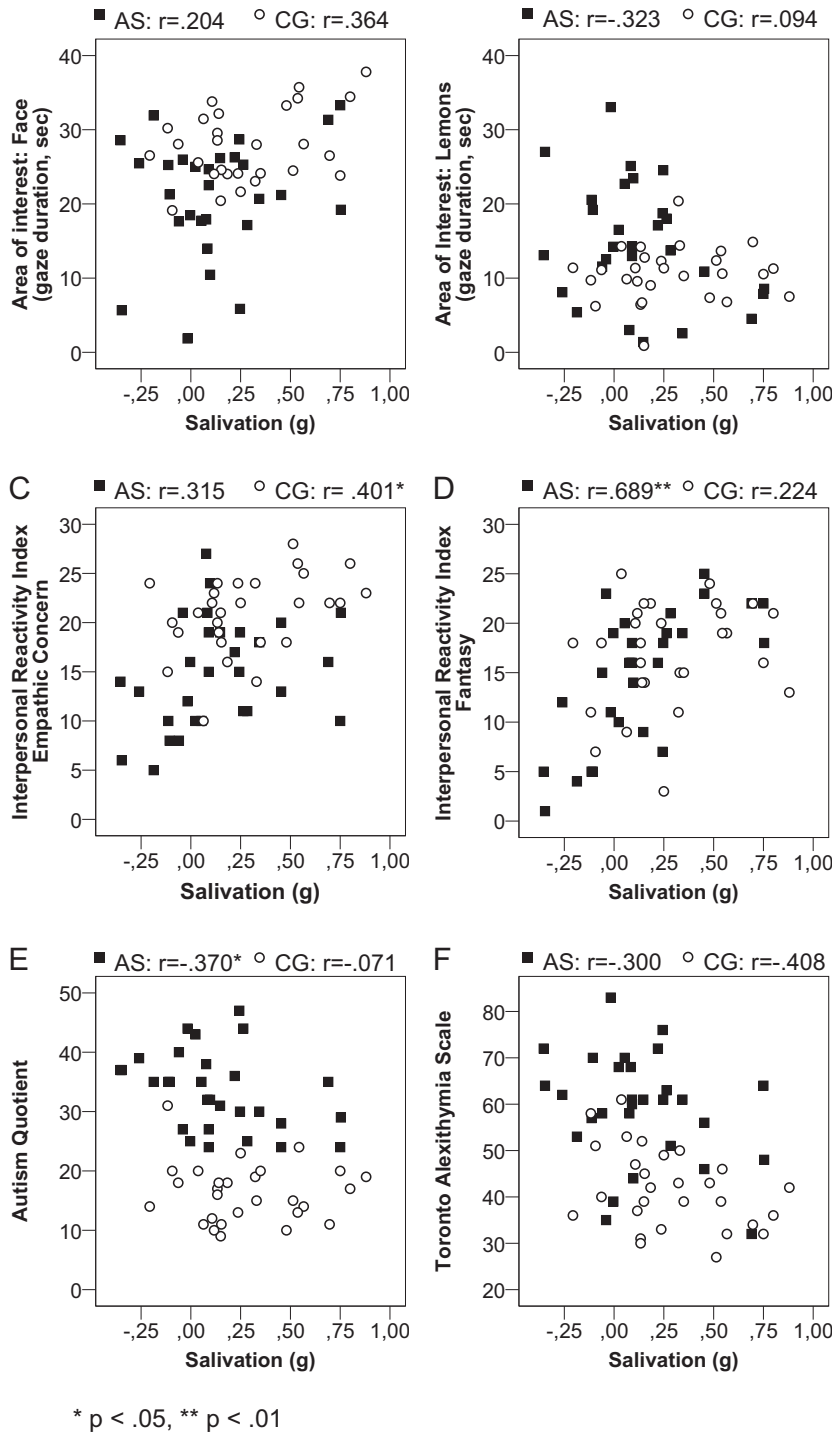
Stepwise linear regressions were performed with the outcome variable salivation and the predictors Age, AOL\_face, AQ, IRI\_EC, and IRI\_FS separately for the two groups (Table 2). Component TAS had to be removed because of its strong correlation with IRI\_FS. Our analysis revealed that the significant predictors of induced salivation differed between the two groups: higher values on the IRI\_FS and older age predicted a stronger salivation in the AS group, whereas higher values on the IRI\_EC and more attention to the face (AOL\_face) predicted a stronger salivation induction in the CG.

## 4. Discussion

Our study was aimed at assessing a basic empathy-related process in ASD while reducing bias due to complex instructions and participants' cognitive influences. We applied the salivation test, which examines resonance at the autonomic level and entails minimal instruction that does not require a specific action by the participant. To explore the possible effects of atypical visual orientation to the stimulus, we assessed spontaneous gaze behavior with eye-tracking.

Although mean salivation was significantly lower in the AS group than in the CG, any substantive difference between them was rather small ( $r = .2$ ). Furthermore, the variances were similar for both groups and indicated that salivation-induction occurred for most of the AS participants. Therefore, the presence or absence of resonance at the autonomic level was not restricted to the categorical diagnosis of AS. This finding emphasizes the current notion of the spectrum character of autistic disorders, that is reflected in the recent changes to the newly defined diagnosis "Autism spectrum disorder" in the DSM-5 (American Psychiatric Association, 2013).

However, the underlying mechanisms appeared to differ between groups. For persons in the AS group, stronger salivation-induction was related to higher age and more self-reported empathic fantasizing – a cognitive component of



**Fig. 3.** Correlations of induced salivation with gaze behavior (panels A and B), empathic (panels C and D) and autistic traits (panel E), and alexithymia (panel F) in the Asperger syndrome (AS,  $n = 29$ ) and the control (CG,  $n = 28$ ) groups.

empathy. For those in the CG, salivation was positively related with self-reported empathic concern – an emotional component of empathy – as well as with the visual focus on the squinching face.

In investigations by Pavlov (1927) of the reflex that links a visual stimulus and an autonomic reaction, the mere perception of food automatically activated related representations. This then generated a corresponding bodily reaction such as salivation, i.e., a perception-action link in a non-social setting. Thus, the conditioned reaction described by Pavlov would link the visual perception of lemons with the bodily reaction of salivation. However, we noted here that control participants

**Table 2**  
Results of the stepwise linear regression in the Asperger syndrome (AS) and the control (CG) groups.

	<i>b</i>	SE <i>b</i>	$\beta$	<i>p</i>
<b>AS<sup>a</sup></b>				
Step 1				
Constant	−0.31	0.10		
IRI fantasy	0.03	0.01	0.67	<.001
Step 2				
Constant	−0.60	0.13		
IRI fantasy	0.03	0.01	0.63	<.001
Age	0.01	0.00	0.38	.02
<b>CG<sup>b</sup></b>				
Step 1				
Constant	−0.33	0.28		
IRI empathic concern	0.03	0.01	0.40	.03
Step 2				
Constant	−0.93	0.38		
IRI empathic concern	0.03	0.01	0.40	.02
AOI_face	0.02	0.01	0.37	.04

<sup>a</sup>  $R^2 = .45$  for Step 1,  $\Delta R^2 = .14$  for Step 2 ( $p = .02$ ).

<sup>b</sup>  $R^2 = .16$  for Step 1,  $\Delta R^2 = .14$  for Step 2 ( $p = .04$ ).

showed higher salivation the longer they focused on the face in the video. This suggests that, in the control participants, the perception of someone biting into the lemon, that is, the social component of the stimulus, was relevant for eliciting a salivation response rather than the mere sight of the food. Furthermore, induced salivation was predicted by self-reported empathic concern in the CG. The scale for that component evaluates the degree to which a respondent experiences feelings of warmth, compassion, and concern for the observed individual (Davis, 1980, 1983). Here, we found that the induced-salivation response was related to the extent to which a participant acknowledged emotional reactivity toward other people. In addition, salivation was negatively correlated with alexithymia. Deficits in insight into one's own emotional state may therefore constrain the capacity for sharing the physiological and emotional states of others, as shown previously (Bernhardt & Singer, 2012). Taken together, our findings support the belief that an autonomic salivation response is embedded within the broader framework of empathy.

Compared with persons in the CG, those in the AS group looked significantly less at the face of the stimulus. This is in line with observations in other studies (Falck-Ytter & von Hofsten, 2011). However, contrary to our expectation, our results showed that this difference in gaze behavior for individuals with ASD was not decisive for their empathic resonance response. Within the AS group, induced salivation was highest in those describing themselves as empathic fantasizers. High fantasizers are characterized as “devoting time and intellectual involvement to the nonsocial world of books, movies, and television” (Davis, 1983, p. 125). According to Davis (Davis, 1983), such persons have greater verbal abilities but are rather introverted and feel uncomfortable in social settings. This description matches the clinical impression of well-compensated and socially interested individuals at the lighter end of the autistic spectrum.

Salivation was also highest in older participants of the AS group. Previous studies have shown that empathy-related abilities increase with age in individuals with ASD. Those features include facial mimicry (Thioux & Keysers, 2010), changes in the neural substrates of empathy (Schulte-Ruther et al., 2013), imitation skills (Williams, Whiten, & Singh, 2004), cognitive and affective empathy skills (Schwenck et al., 2012) and overall social functioning (Bastiaansen et al., 2011). This shows that persons with ASD may continuously learn to improve their social abilities over the course of their lives. In accord with those earlier investigations, we were able to relate the autonomic resonance in AS measured here with two variables – age and self-reported empathic fantasizing – that might indicate the development of social maturity and compensatory mechanisms. This could mean that individuals with AS become more familiar with social situations, depending upon their previous life experience (age) and the intensity of their explicit intellectual occupation with social contents (fantasizing). This conclusion is also in line with our general clinical experience. That is, persons with ASD use explicitly acquired intellectual strategies whereas individuals with typical development can rely on implicit, intuitive processes.

Some limitations must be considered for this study. Although we presumed that salivation is less prone to cognitive influences by participants (such as intentional manipulation) than are other resonance paradigms, we did not explicitly control for that criterion. Although evidence exists for the possible voluntary control of salivation by imagery such as meditation (White, 1978), it appears that this manipulation must be intentionally executed. However, it seems unlikely that our participants deliberately tried to influence their salivary flow because they were not explicitly informed about the exact purpose of the test until the end of the experiment. In addition, the salivary response may have been unconsciously altered, for example, due to stress or distractions associated with an unknown research environment. However, because stress and anxiety are known to reduce salivary flow (Power & Thompson, 1970), we would have expected our present findings to be even more pronounced if there had been any effect by those factors. Eye-tracking data did not reveal that participants in the AS group looked more toward the outside of the screen. Therefore, we assume that they were not more visually distracted than the other participants.

## 5. Conclusion

In summary, basic empathic resonance, as measured by salivation-induction, was similar between individuals with ASD and our control participants. However, the underlying mechanisms differed. In both groups, a social component was relevant for empathic resonance to emerge, albeit on different levels: the explicit level for AS participants, i.e., intellectual involvement with social content over time, versus the implicit level for control participants, i.e., emotional reactivity and the mere presence of a social vis-à-vis. From this we conclude that individuals with ASD can profit from life-long intellectual training of their social abilities. These findings also suggest that fostering social interests, if only in the abstract, can influence more implicit basic empathic mechanisms over time. Therefore, autistic empathy is not an oxymoron.

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## References

- American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.
- Bagby, R. M., Parker, J. D., & Taylor, G. J. (1994). The twenty-item Toronto Alexithymia Scale-I. Item selection and cross-validation of the factor structure. *Journal of Psychosomatic Research*, 38(1), 23–32.
- Bagby, R. M., Taylor, G. J., & Parker, J. D. (1994). The Twenty-item Toronto Alexithymia Scale-II. Convergent, discriminant, and concurrent validity. *Journal of Psychosomatic Research*, 38(1), 33–40.
- Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from Asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders*, 31(1), 5–17.
- Bastiaansen, J. A., Thioux, M., Nanetti, L., van der Gaag, C., Ketelaars, C., & Minderaa, R. (2011). Age-related increase in inferior frontal gyrus activity and social functioning in autism spectrum disorder. *Biological Psychiatry*, 69(9), 832–838.
- Bernhardt, B. C., & Singer, T. (2012). The neural basis of empathy. *Annual Review of Neurosciences*, 35, 1–23.
- Cacioppo, J. T., Petty, R. E., Losch, M. E., & Kim, H. S. (1986). Electromyographic activity over facial muscle regions can differentiate the valence and intensity of affective reactions. *Journal of Personality and Social Psychology*, 50(2), 260–268.
- Davis, M. H. (1980). A multidimensional approach to individual differences in empathy. *Catalog of Selected Documents in Psychology*, 10, 85–100.
- Davis, M. H. (1983). Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of Personality and Social Psychology*, 44(1), 113–126.
- Doppelt, J. E. (1956). Estimating the full scale score on the Wechsler Adult Intelligence Scale from scores on four subtests. *Journal of Consulting Psychology*, 20(1), 63.
- Eisenberg, N., & Lennon, R. (1983). Sex differences in empathy and related capacities. *Psychological Bulletin*, 94(1), 100–131.
- Falck-Ytter, T., & von Hofsten, C. (2011). How special is social looking in ASD: A review. *Progress in Brain Research*, 189, 209–222.
- Gonzalez-Liencre, C., Shamay-Tsoory, S. G., & Brüne, M. (2013). Towards a neuroscience of empathy: Ontogeny, phylogeny, brain mechanisms, context and psychopathology. *Neuroscience and Biobehavioral Reviews*, 37(8), 1537–1548.
- Hagemuller F., Rössler W., Wittwer A. and Haker H., (1985) Juicy lemons for measuring empathic resonance, *submitted*.
- Haker, H., Schimansky, J., & Rössler, W. (2010). Soziophysiologie: Grundlegende Prozesse der Empathiefähigkeit. *Neuropsychiatrie*, 24(3), 151–160.
- Happé, F., & Frith, U. (1996). Theory of mind and social impairment in children with conduct disorder. *British Journal of Developmental Psychology*, 14(4), 385–398.
- Klin, A., Jones, W., Schultz, R., & Volkmar, F. (2003). The enactive mind, or from actions to cognition: Lessons from autism. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 358(1430), 345–360.
- Klin, A., Jones, W., Schultz, R., Volkmar, F., & Cohen, D. (2002a). Defining and quantifying the social phenotype in autism. *American Journal of Psychiatry*, 159(6), 895–908.
- Klin, A., Jones, W., Schultz, R., Volkmar, F., & Cohen, D. (2002b). Visual fixation patterns during viewing of naturalistic social situations as predictors of social competence in individuals with autism. *Archives of General Psychiatry*, 59(9), 809–816.
- Langdell, T. (1978). Recognition of faces: An approach to the study of autism. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 19(3), 255–268.
- Levenson, R. W., & Ruef, A. M. (1992). Empathy: A physiological substrate. *Journal of Personality and Social Psychology*, 63(2), 234–246.
- Lord, C., Risi, S., Lambrecht, L., Cook, E. H., Jr., Leventhal, B. L., & DiLavore, P. C. (2000). The autism diagnostic observation schedule-generic: A standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders*, 30(3), 205–223.
- Lord, C., Rutter, M., & Le Couteur, A. (1994). Autism diagnostic interview-revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders*, 24(5), 659–685.
- Magnee, M. J., de Gelder, B., van Engeland, H., & Kemner, C. (2007). Facial electromyographic responses to emotional information from faces and voices in individuals with pervasive developmental disorder. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 48(11), 1122–1130.
- McIntosh, D. N., Reichmann-Decker, A., Winkelman, P., & Wilbarger, J. L. (2006). When the social mirror breaks: Deficits in automatic, but not voluntary, mimicry of emotional facial expressions in autism. *Developmental Science*, 9(3), 295–302.
- McLennan, J. D., Lord, C., & Schopler, E. (1993). Sex differences in higher functioning people with autism. *Journal of Autism and Developmental Disorders*, 23(2), 217–227.
- Morelli, S. A., & Lieberman, M. D. (2013). The role of automaticity and attention in neural processes underlying empathy for happiness, sadness, and anxiety. *Frontiers in Human Neuroscience*, 7, 160.
- Nemiah, J. C. (1977). Alexithymia. *Psychotherapy and Psychosomatics*, 28(1–4), 199–206.
- Nirenberg, T. D., & Miller, P. M. (1982). Salivation: An assessment of food craving? *Behaviour Research and Therapy*, 20(4), 405–407.
- Norscia, I., & Palagi, E. (2011). Yawn contagion and empathy in *Homo sapiens*. *PLoS ONE*, 6(12), e28472.
- Papoiu, A. D. P., Wang, H., Coghill, R. C., Chan, Y. H., & Yosipovitch, G. (2011). Contagious itch in humans: A study of visual 'transmission' of itch in atopic dermatitis and healthy subjects. *British Journal of Dermatology*, 164(6), 1299–1303 <http://dx.doi.org/10.1111/j.1365-2133.2011.10318.x>
- Pavlov, I. P. (1927). *Conditioned reflexes: An investigation of the physiological activity of the cerebral cortex*. Oxford: Oxford Univ Press.
- Platek, S. M., Critton, S. R., Myers, T. E., & Gallup, G. G. (2003). Contagious yawning: The role of self-awareness and mental state attribution. *Brain Research. Cognitive Brain Research*, 17(2), 223–227.



- Power, R. P., & Thompson, W. T. (1970). Simulation of introversion and extraversion on lemon test. *British Journal of Psychology*, *61*(1), 91–93.
- Press, C., Richardson, D., & Bird, G. (2010). Intact imitation of emotional facial actions in autism spectrum conditions. *Neuropsychologia*, *48*(11), 3291–3297 <http://dx.doi.org/10.1016/j.neuropsychologia.2010.07.012>
- Preston, S. D., & de Waal, F. B. (2002). Empathy: Its ultimate and proximate bases. *Behavioral and Brain Sciences*, *25*(1), 1–20.
- Provine, R. R. (2005). Contagious yawning and laughing: Everyday imitation- and mirror-like behavior. *Behavioral and Brain Sciences*, *28*(02), 142.
- Schulte-Rüther, M., Greimel, E., Piefke, M., Kamp-Becker, I., Remschmidt, H., & Fink, G. R. (2013). Age-dependent changes in the neural substrates of empathy in autism spectrum disorder. *Social Cognitive and Affective Neuroscience*.
- Schwenck, C., Mergenthaler, J., Keller, K., Zech, J., Salehi, S., & Taurines, R. (2012). Empathy in children with autism and conduct disorder: Group-specific profiles and developmental aspects. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *53*(6), 651–659.
- Senju, A. (2013). Atypical development of spontaneous social cognition in autism spectrum disorders. *Brain and Development*, *35*(2), 96–101.
- Senju, A., Kikuchi, Y., Akechi, H., Hasegawa, T., Tojo, Y., & Osanai, H. (2009). Brief report: Does eye contact induce contagious yawning in children with autism spectrum disorder? *Journal of Autism and Developmental Disorders*, *39*(11), 1598–1602.
- Senju, A., Maeda, M., Kikuchi, Y., Hasegawa, T., Tojo, Y., & Osanai, H. (2007). Absence of contagious yawning in children with autism spectrum disorder. *Biology Letters*, *3*(6), 706–708.
- Thioux, M., & Keysers, C. (2010). Empathy: Shared circuits and their dysfunctions. *Dialogues in Clinical Neuroscience*, *12*(4), 546–552.
- Wechsler, D. (1981). *Manual for the Wechsler Adult Intelligence Scale – Revised*. San Antonio, TX: Psychological Corporation.
- White, K. D. (1978). Salivation – Significance of imagery in its voluntary control. *Psychophysiology*, *15*(3), 196–203 <http://dx.doi.org/10.1111/j.1469-8986.1978.tb01363.x>
- Williams, J. H., Whiten, A., & Singh, T. (2004). A systematic review of action imitation in autistic spectrum disorder. *Journal of Autism and Developmental Disorders*, *34*(3), 285–299.