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Comparing the broad socio-cognitive profile of youth with Williams syndrome and 22q11.2 deletion syndrome

O. Weisman,[1,2] R. Feldman,[3] M. Burg-Malki,[1,4] M. Keren,[4,5] R. Geva,[3] G. Diesendruck[3] & D. Gothelf[1,2,4]

1 *The Behavioral Neurogenetics Center, The Edmond and Lily Safra Children's Hospital, Sheba Medical Center, Tel Hashomer, Israel*
2 *Sagol School of Neuroscience, Tel Aviv University, Tel Aviv, Israel*
3 *Department of Psychology and Gonda Brain Research Center, Bar-Ilan University, Ramat Gan, Israel*
4 *Sackler School of Medicine, Tel Aviv University, Tel Aviv, Israel*
5 *Child and Adolescent Division, Geha Mental Health Center, Petah Tikva, Israel*

Abstract

Background Numerous studies have assessed the socio-cognitive profile in Williams syndrome (WS) and, independently, in 22q11.2 deletion syndrome (22q11.2DS). Yet, a cross-syndrome comparison of these abilities between individuals with these two syndromes with known social deficits has not been conducted.

Methods Eighty-two children participated in four study groups: WS (n = 18), 22q112.DS (n = 24), age-matched individuals with idiopathic developmental disability (IDD; n = 20) and typically developing (TD) controls (n = 20). Participants completed four socio-cognitive tests: facial emotion recognition, mental state attribution, differentiating real from apparent emotions and trait inference based on motives and actions-outcomes.

Results The current findings demonstrate that children with WS were better in labelling happy faces compared with children with 22q11.2DS, partially reflecting their exaggerated social drive. In the false belief task, however, the WS and IDD groups performed poorly compared with the 22q11.2DS group, possibly due to their difficulty to interpret subtle social cues. When asked to identify the gap between real-negative vs. apparent-positive emotions, the 22q11.2DS group performed similarly to TD children but better than the WS group, possibly due to their anxious personality and their innate bias towards negatively valence cues. Finally, individuals with WS were more willing to become friends with a story character even when the character's motives were negative, reflecting their difficulty to avoid potentially harmful real-life situations.

Conclusions Overall, our multi-facet socio-cognitive battery uncovered strengths and weaknesses in social cognition that are syndrome-specific, shared among the genetic syndromes, or common to the three clinical groups compared with healthy controls. Our findings underscore the need to devise age-specific and condition-specific assessment tools and intervention programs towards improving these children's socio-cognitive deficits.

Keywords children, DiGeorge, neurogenetic disorders, social cognition, theory of mind (ToM), velocardiofacial syndrome

Correspondence: Prof Doron Gothelf and Dr Omri Weisman, Sagol School of Neuroscience, Tel Aviv University, and The Behavioral Neurogenetics Center, The Edmond and Lily Safra Children's Hospital, Sheba Medical Center, Tel Hashomer 52621, Israel. Tel: 972-3-530-2663; Fax: 972-77-349-8317 (e-mail: gothelf@post.tau.ac.il; omweisman@gmail.com).

Introduction

Williams syndrome (WS) and chromosome 22q11.2 deletion syndrome (22q11.2DS) are two neurogenetic disorders with prevalence rates of 1:7500 and 1:4000 live births, respectively (Strømme *et al.* 2002; Botto *et al.* 2003; Shprintzen 2008; Grati *et al.* 2015).

Individuals with WS usually present mild to moderate intellectual disability [with an average full-scale IQ score (FSIQ) of 60 points], coupled with weakness in executive and visuospatial abilities (Bellugi *et al.* 1994; Zarchi *et al.* 2014). However, their language and short-term verbal memory abilities are considered to be relatively intact (Mervis 2003).

In terms of their social phenotype, individuals with WS are hyper-social, demonstrate excessive desire to approach people, exhibit indiscriminate trust towards others (Martens *et al.* 2008) and are extremely attracted to human faces (Pober 2010; Vivanti *et al.* 2017b). As such, their performance on tasks that require the processing of human facial expressions or the categorisation of affective facial stimuli is relatively preserved (Santos *et al.* 2009; Dodd *et al.* 2010), and it appears to be commensurate with mental age, rather than chronological age.

Conversely, their understanding of others' mental states (such as others' false beliefs) is impaired, and they often have difficulties to understand intricate or ironic social circumstances (Deutsch *et al.* 2007). As a result, they usually stumble upon their naïve and overtrusting personality when confronted with social situations that involve disguise, conflicting interests and social complexity (Porter *et al.* 2008; Santos and Deruelle 2009). Other studies have reported that individuals with WS also show a specific impairment in recognising angry or negative faces (Plesa-Skwerer *et al.* 2006; Porter *et al.* 2010).

The cognitive profile of individuals with 22q11.2DS is characterised by an average FSIQ score of 75 points (at the borderline range; Swillen *et al.* 1999), alongside adequate visuospatial and numerical processing but impaired verbal processing (Bearden *et al.* 2001; Simon *et al.* 2005; Gothelf 2007). They usually exhibit extreme shyness, avoidance, coupled with restricted affect (Shprintzen 2008; Schonherz *et al.* 2014; Swillen and McDonald-Mcginn 2015) and deficient ability to categorise facial stimuli (Andersson *et al.* 2008; Campbell *et al.* 2010). Other studies point for impairments in false belief and emotion attribution abilities in 22q11.2DS compared with typically developing (TD) controls (Campbell *et al.* 2015). A recent review of 16 studies further confirmed that social cognition is impaired in 22q11.2DS, especially abilities such as emotion processing and complex theory of mind (Norkett *et al.* 2017).

Several studies have compared neuropsychiatric and neurocognitive profiles between the two syndromes (Zarchi *et al.* 2014; Weinberger *et al.* 2016). Zarchi *et al.* (2014) showed that individuals with WS are characterised by more severe impairments in both executive and visuospatial functions compared with 22q11.2DS, but that the two syndromes exhibit similarly deficient performance IQ and verbal IQ, when compared with individuals with idiopathic developmental disability (IDD) and TD controls.

Yet, research that looks into and compares between the socio-cognitive profiles of individuals harbouring these microdeletions is missing. Moreover, contrasting the syndromes against individuals with IDD and TD controls is likely to be informative, as it may uncover patterns that are unique to the syndromes but differ from that seen in IDD or that are shared between the three clinical groups vs. TD controls. This comparison is expected to promote our understanding of nonverbal deficits in these neurogenetic conditions, potentially paving the way for the development of adequate interventions.

While some studies compared between the socio-cognitive abilities of WS, 22q11.2DS and those with autism spectrum disorder (ASD), findings highlight fundamental differences between the groups that merit that such an investigation will be conducted independently. As such, we focused on the two syndromes while referring to the IDD and TD groups as controls.

Considering the above, the current study sought to compare the socio-cognitive performance of children with WS, 22q11.2DS, IDD and TD, across a range of tasks, including (1) facial emotion recognition task – testing the ability to infer emotional states from facial stimuli; (2) first-order false belief task – testing the ability to represent others' thoughts and perspectives; (3) a paradigm that assesses the ability to differentiate between real (i.e. concealed) vs. apparent emotions; and, finally, (4) a paradigm that tests one's capacity to infer others' traits based on their motives and actions-outcomes.

We hypothesised that as compared with the 22q11.2DS and IDD groups, individuals with WS will demonstrate better ability to recognise emotions from facial stimuli, especially when stimuli are coupled with verbal descriptors. This superior ability would be emotion-specific, given prior findings of impaired recognition of angry faces in WS. However, individuals with WS are expected to perform worse than the 22q11.2DS and IDD groups on tasks that require to grasp others' mental states (also referred to as mental attribution). Finally, individuals with 22q11.2DS are likely to recognise others' negative emotions even if they are concealed due to their anxious and alert personality and their inclination towards negative social cues (Shprintzen 2008).

Method

Participants

The study sample included 82 children: 18 participants with WS, 24 participants with 22q11.2DS, 20 participants with IDD and 20 TD participants. The three clinical groups were between 7 and 15 years of age. The chronological age of TD controls served as a proxy for their mental age (MA) and as the basis for matching them with the three clinical groups (refer to Table 1 for additional data). The diagnosis of 22q11.2DS and WS was confirmed in all affected individuals by fluorescent in situ hybridisation and by multiplex ligation probe amplification (Michaelovsky *et al.* 2012). The WS and 22q11.2DS participants were recruited from the Behavioural Neurogenetics Centre at a large tertiary referral centre in Israel. Participants with IDD were recruited from schools for special education for children and adolescents with developmental disability. TD controls were recruited through advertisements within the local community. They were all students in mainstream classes, and none had a major psychopathology. The study was approved by the local Institutional Review Board committee. Written informed consents were obtained from the parents of all children prior to their participation in the study.

Behavioural paradigms

Facial emotion recognition

Participants' ability to correctly *label* and *match* facial stimuli was assessed using a task especially developed for this study. Stimuli consisted of 24 short coloured video clips of male and female actors (Baron-Cohen *et al.* 2013) presented on a computer screen (23 × 30 cm wide), representing six basic emotions: happiness, sadness, anger, fear, disgust and surprise; i.e. four clips for each emotion. The average duration of the clips was 5.47 s (*sd* = 0.76; range: 3.2–7.4 s). The bank of stimuli was originally developed for learning and practicing purposes for individuals with ASD and later adopted for research. For details about the validity of stimuli, refer to www.jkp.com/

Table 1 Demographic characteristics of participants in the four study groups ($N = 82$)

	WS	22q11.2DS	IDD	TD	ANOVA *F*	Comparisons
N	18	24	20	20		
Child's age, years	11.96 (2.33)	11.41 (1.96)	10.86 (2.72)	7.82 (2.38)	$F_{3,78} = 12.33^{***}$	TD < WS, 22q11.2, IDD
Mental age	7.82 (1.36)	9.5 (2.01)	7.83 (2.00)	7.82 (2.38)	$F_{3,74} = 3.75^{*}$	*n.s.*
IQ	67.63 (8.78)	83.57 (11.95)	73.84 (9.52)		$F_{2,75} = 11.70^{***}$	22q11.2DS > WS, IDD
PIQ	68.19 (9.95)	85.64 (11.42)	75.43 (14.17)		$F_{2,48} = 10.52^{***}$	22q11.2DS > WS, IDD
VIQ	67.94 (11.83)	83.27 (12.21)	77.77 (12.54)		$F_{2,48} = 7.36^{**}$	22q11.2DS > WS
Gender (M/F)	9/9	17/7†	14/6†	11/9		

Mean (SD). Mental age (MA) was calculated as MA = [IQ × CA] / 100.

WS, Williams syndrome; 22q11.2DS, 22q11.2 deletion syndrome; IDD, idiopathic developmental disability; TD, typically developing (control group); ANOVA, analysis of variance.

†Chi-squared analysis (X^2), $P < 0.05$.

*$P < 0.05$.

**$P < 0.01$.

***$P < 0.001$.

mindreading. Moreover, as part of a pilot test, 20 students were presented with 8 video clips for each emotion (48 videos in total). Participants were then asked to specify the emotion shown and its intensity level (on a 1–4 Likert scale). Half of stimuli (24 videos) were selected for the study based on the likelihood that they will be identified correctly and with equivalent mean intensity between the different emotions.

Participants were asked to answer two questions about each video clip. In the *labelling* module, the experimenter provided four emotion labels (e.g. 'happy', 'sad', etc.), and participants were prompted to choose the label that best fits the stimulus they just saw. In the *matching* module, participants watched the same video clip again followed by three videos: two distractor videos and one identical to the target stimulus. The entire task took about 35–40 min to complete. Correct answer credited participants with 1 point. Because less than half of TD participants gave correct answers on two of the labelling items (representing fear), these items were excluded from further analysis, resulting in a total score of 22 in the labelling module and 24 in the matching module.

False belief

Participants were assessed with two false belief tasks (Wimmer and Perner 1983). In the first task, participants were shown a familiar container (with a picture of cookies on it) that, when opened, revealed an unexpected content (pencils). Children were asked: "*What your mother will think is in the box?*". This task requires to impute to another person a false belief about the content of the box (which differs from both reality and what the child knows to be true). A correct answer would credit 1 point.

In the second false belief task, participants were presented with four scenarios in which a character places an object in a specific location and then exits the room. In his/her absence, the object is moved to a new location. Children were asked three questions: "*Upon his return, where will the character think the object is?*", "*Where will the character look for the object?*" and "*Why will the character look for the object there?*". Two (out of four) scenarios were adapted from an earlier study (Shatz *et al.* 2003), while two scenarios were especially created for the current study. Providing correct answers to the first two questions would credit 1 point. Referring to the character's false belief in the third question would credit 2 points. Scoring in this task ranged between 0 and 4 points for each of the scenarios (16 points in total for 4 scenarios); thus, the overall scoring in the two false belief tasks ranged between 0 and 17 points.

Differentiating real from apparent emotions

In this task, adapted from Harris *et al.* (1986), children were asked to listen to four stories in which it would be appropriate for the character to feel a positive or negative emotion but to hide that emotion. Participants were then asked: "*How will the character look like (referring to perceived emotion)?*" and "*How will the character really feel (referring to real emotion)?*". Next, the experimenter assessed whether the child grasped the difference between real and apparent emotion (in the right direction); finally, participants were requested to elaborate (justify) their answers. Each correct answer in the first three questions would credit 1 point. Explaining why the character expresses different emotions than the one felt would credit 2 additional points (but only 1 point for answering correctly without referring to the hidden emotion). Thus, scoring in this task ranged between 0 and 8, reflecting overall task performance.

Traits' inference based on motives and actions-outcomes

Children's ability to infer others' traits based on their motives or their actions was assessed using a task developed by Heyman and Gelman (1998). Participants were presented with four illustrated stories in which a character's motives were either positive or negative, while the outcome of his/her action was the opposite. For example, in one of the stories, a girl (the character) sprinkles water on her friend. A positive motive in that story would be that the girl wanted to make her fried feel cooler because of the weather, although the outcome was negative (i.e. the friend got angry about getting wet). An opposite scenario would read as negative motive (i.e. to get the other person wet) coupled with a positive outcome (i.e. that person enjoyed getting wet). Children were asked four questions: "*Do you think the character is nice/mean?*", "*Do you think what the character did was nice/mean?*", "*Would you like to be friends with the character?*" Possible answers included 'yes', 'maybe' and 'no'. Answering maybe would

qualify for half a point. The last question was "*Do you think the character would help another child who fell in the park?*". Answers that matched the character's motive were regarded as correct (i.e. worthy of 1 point).

Procedure

The initial meeting with children in the three clinical groups and their parents (usually the mother) were held at the Behavioural Genetics Centre and the adjunct clinic. An intelligence test was conducted at the first session; FSIQ scores of individuals in the three clinical groups were assessed using the Wechsler Intelligence Scale for Children-Revised (Wechsler 1974). The FSIQ scores of control participants are missing because of the Institutional Review Board restraints on administering IQ tests to TD children. Second meeting was held either at the clinic or at children's home, as preferred (8 of 18 WS subjects asked to conduct the second meeting at home, so thus 13 of 24 22q11.2DS subjects and 9 of 20 IDD subjects). Children in the TD group were tested at home.

The socio-cognitive battery was employed by one of the authors of the current study (M.B-M.) as part of her doctoral thesis and clinical training. The emotion recognition paradigm took 30–45 min to complete, including breaks to accommodate to the child's attention span etc. Next, the three socio-cognitive tests (mental state attribution, differentiating real from apparent emotions and trait inference) were employed according to a predefined randomised order. Occasional breaks between the tests were taken when needed. The parent was not present at the room during the tests.

Planned analyses

Two steps were taken to count for group differences in MA and FSIQ scores. As a first step, statistical analyses were conducted while controlling for MA. As a second step, each analysis was conducted twice – once with a sample of 82 participants which differed in FSIQ (with 22q11.2DS having the highest score, then IDD and finally WS) and a second analysis with a smaller sample of 70 participants (comprising the three clinical groups) which were matched in terms of FSIQ. Because the findings of the larger sample did not differ from the findings of the smaller sample, we further detail the analysis based on the larger cohort (n = 82). Statistical analyses conducted for each of the tasks is detailed at the beginning of each of the succeeding mentioned sections.

Post hoc Bonferroni comparisons were computed where appropriate.

Results

Facial emotion recognition

Separate mixed-design analysis of covariance (ANCOVA) was computed for each of the modules in the facial emotion recognition task (i.e. labelling and matching) with valence being the within-subject variable and group being the between-subject variable, respectively. Participants' FSIQ score was treated as covariate in the analysis (as well as in the analyses detailed further in the succeeding texts).

In the labelling module, an interaction of group by valence was found, $F_{3,73} = 5.01$, $P < 0.01$. Breaking down this interaction by valence revealed that the WS group was better in labelling positive emotions compared with the 22q11.2DS group, $F_{3,73} = 2.77$, $P < 0.05$ (refer to Table 2 for additional data). The effect was dominated by WS labelling 'happy' faces more accurately than the 22q11.2DS, $F_{3,73} = 2.54$, $P < 0.05$, as revealed by a *post hoc* analysis. When asked to label negative emotions, the TD group showed superior ability compared with the three clinical groups, $F_{3,73} = 8.22$, $P < 0.001$. The latter finding replicated in the matching module, with TD participants exhibiting higher performance than all three clinical groups when asked to match negative or positive emotions, P's < 0.001. All participants labelled positive stimuli more accurately than negative stimuli, above and beyond group identity, $F_{1,73} = 9.86$, $P < 0.01$.

False belief

Univariate ANCOVA was employed to uncover group differences in the false belief task. A main effect of group was found, $F_{3,73} = 13.40$, $P < 0.001$. Bonferroni *post hoc* revealed that TD participants scored higher compared with the three clinical groups and that the 22q11.2DS group showed superior performance compared with the WS and IDD groups (Fig. 1).

Table 2 Group comparisons of performance in the facial emotion recognition paradigm

	WS	22q11.2DS	IDD	TD	ANOVA *F*	Comparisons
Labelling, mean (±SD)						
Happy	3.62 (±0.61)	2.78 (±1.04)	3.15 (±0.83)	3.10 (±0.96)	$F_{3,73} = 2.54$*	WS > 22q11.2DS
Sad	2.87 (±1.02)	2.78 (±0.99)	3.26 (±0.93)	3.75 (±0.44)	$F_{3,73} = 5.38$**	TD > WS, 22q11.2DS, IDD
Scared	1.43 (±0.62)	1.21 (±0.67)	1.10 (±0.87)	1.45 (±0.60)		
Angry	3.37 (±0.61)	3.26 (±0.75)	3.42 (±0.69)	3.70 (±0.65)		
Disgust	2.37 (±1.20)	3.00 (±1.08)	2.73 (±1.14)	3.50 (±0.76)	$F_{3,73} = 4.72$**	TD > WS, 22q11.2DS
Surprised	2.18 (±1.04)	2.47 (±1.12)	2.05 (±1.22)	2.70 (±1.03)		
Overall	17.33 (±0.59)	15.87 (±0.52)	17.19 (±0.54)	19.35 (±0.53)	$F_{3,73} = 7.13$***	TD > 22q11.2DS, IDD
Matching, mean (±SD)						
Happy	2.68 (±0.79)	3.13 (±0.69)	2.73 (±0.73)	3.65 (±0.58)	$F_{3,73} = 7.62$***	TD > WS, IDD
Sad	2.68 (±0.60)	2.60 (±0.83)	2.52 (±0.84)	3.30 (±0.65)	$F_{3,73} = 4.79$**	TD > 22q11.2DS, IDD
Scared	2.93 (±0.35)	3.34 (±0.88)	3.00 (±0.74)	3.60 (±0.75)		
Angry	3.31 (±0.70)	3.56 (±0.58)	3.36 (±0.76)	3.75 (±0.44)		
Disgust	3.37 (±0.71)	3.47 (±0.66)	3.42 (±0.90)	3.90 (±0.76)	$F_{3,73} = 2.84$*	TD > WS, 22q11.2DS, IDD
Surprised	2.31 (±0.87)	2.56 (±1.23)	2.42 (±1.12)	2.85 (±0.87)		
Overall	17.55 (±0.55)	18.11 (±0.48)	17.71 (±0.51)	21.29 (±0.49)	$F_{3,73} = 12.38$***	TD > WS, 22q11.2DS, IDD

WS, Williams syndrome; 22q11.2DS, 22q11.2 deletion syndrome; IDD, idiopathic developmental disability; TD, typically developing (controls); ANOVA, analysis of variance.
*$P < 0.05$.
**$P < 0.01$.
***$P < 0.001$.

Differentiating real from apparent emotions

Mixed-design ANCOVA with emotion type (apparent/real) and stimuli valence (positive/negative) as the within-subject variables was computed to assess children's ability to differentiate real from apparent emotions. FSIQ was treated as covariate.

A group main effect was found, $F_{3,69} = 8.31$, $P < 0.001$. *Post hoc* comparisons revealed that the TD group had higher scores than the WS and IDD groups, while the 22q11.2DS group performed similarly to the rest of the groups (Fig. 2). However, when asked to identify the shift between the character's real and apparent emotions, the WS and IDD groups showed lower abilities compared with TD controls, whereas the 22q11.2DS and TD groups performed comparably well, $F_{3,73} = 5.40$, $P < 0.01$. All three clinical groups had difficulty to identify the shift between *real-positive* and *apparent-negative* emotions compared with TD, $F_{3,73} = 8.98$, $P < 0.001$.

Finally, a main effect for emotion type was found, as participants across all groups identified real emotions more accurately than apparent emotion, $F_{1,69} = 5.05$, $P < 0.05$ (mean ± SD; 1.74 ± 0.35 vs. 1.35 ± 0.69). An interaction between emotion type and stimuli valence emerged, with real emotions of negative valence more accurately identified compared with real emotions of positive valence, $F_{1,69} = 6.35$, $P < 0.05$.

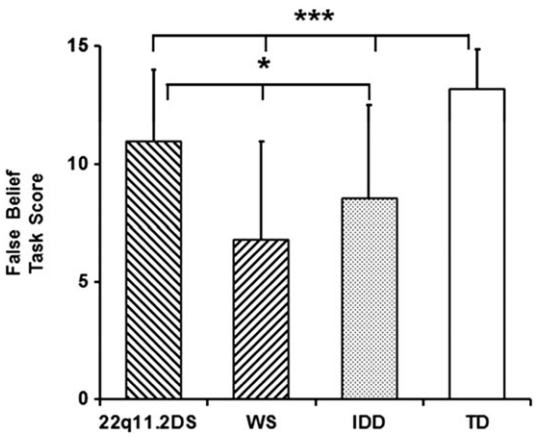

Figure 1 Performance in a first-order false belief task. The 22q11.2DS group showed higher performance compared with the Williams syndrome (WS) and idiopathic developmental disability (IDD) groups. Typically developing (TD) participants demonstrated superior ability compared with all three clinical groups. Error bars depict standard deviations (SD). Mean ± SD: TD: 13.15 ± 1.72 > 22q11.2DS: 10.95 ± 3.03 > IDD: 8.52 ± 4.0, WS: 6.81 ± 4.15; $^{*}P < 0.05$, $^{***}P < 0.001$.

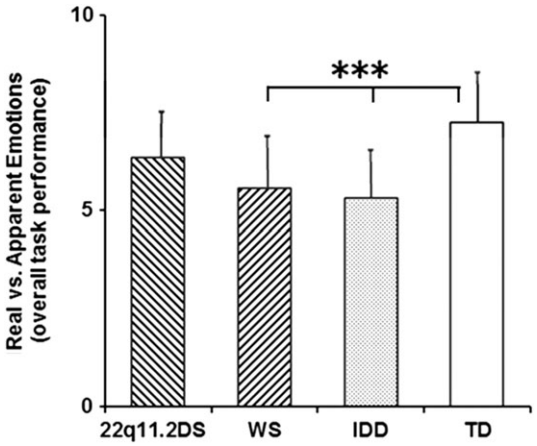

Figure 2 Distinguishing real from apparent emotions. The Williams syndrome (WS) and idiopathic developmental disability (IDD) groups performed poorly compared with TD controls. The 22q11.2DS group performed similarly to TD controls. Error bars depict standard deviations. Mean ± SD: TD: 7.25 ± 1.3 > WS: 5.56 ± 1.5, IDD: 5.32 ± 1.3; 22q11.2DS: 6.35 ± 1.3; $^{***}P < 0.001$.

Inferring traits from motives and actions-outcomes

Mixed-design ANCOVA with motive (positive/negative) as the within-subject variable and group identity as the between-subject variable were computed to examine whether participants rely on the character's motives when asked about his/her traits. Next, finer ANCOVA analyses were conducted to evaluate possible differences in the four questions. Scores on each question for each motive valence were entered as dependent variables (scoring ranged between 0 and 2), and group identity served as the between-subject variable. Analysis was conducted separately for the positive and negative motive scenarios.

Whether the motive was positive or negative did not alter task performance for any of the groups, $P = ns$. In addition, the three clinical groups exhibited significantly lower ability to infer others' traits based on their motives compared with the TD group, $F_{3,73} = 7.77$, $P < 0.001$ (TD: 3.28 ± 0.79 > 22q11.2DS: 2.56 ± 0.94, IDD: 2.36 ± 0.97, WS: 1.96 ± 0.86). When presented with positive scenarios, the TD group answered the first question ("*Do you think the character is nice/mean?*") more accurately than the WS and IDD groups, while the 22q11.2DS group performed comparable with the rest (TD: 1.75 ± 0.63 > IDD: 1.05 ± 0.91, WS: 1.0 ± 0.73; 22q11.2DS: 1.52 ± 0.66). This pattern extended to the second question ("*Do you think what the character did was nice/mean?*"), $F_{3,73} = 5.66$, $P < 0.01$ (TD: 1.6 ± 0.75 > 22q11.2DS: 1.08 ± 0.66, IDD: 0.89 ± 0.65, WS: 0.75 ± 0.77). No difference was found with respect to the last two questions.

Finally, a group main effect was found when children were asked whether they would like to become friends with the character when the character's motive was described as negative, $F_{3,73} = 7.10$, $P < 0.001$. *Post hoc* comparisons indicated that children with WS performed worse in this test than children from the other groups, i.e. they were more willing to become friends with the character (Fig. 3).

Discussion

To the best of our knowledge, this study is the first to directly compare the socio-cognitive profile of children with WS with that of children with 22q11.2DS. As expected, our results uncover a specific socio-cognitive profile in each disorder. In line with our first hypothesis, the WS group was found to be better at labelling happy faces compared with the 22q11.2DS group, possibly due to their disposition towards positive facial stimuli coupled with their intense social appetite (Gagliardi *et al.* 2003; Plesa-Skwerer *et al.* 2006). This pattern was not driven by a general bias to recognise other facial stimuli as happy as their error rate (i.e. erroneously

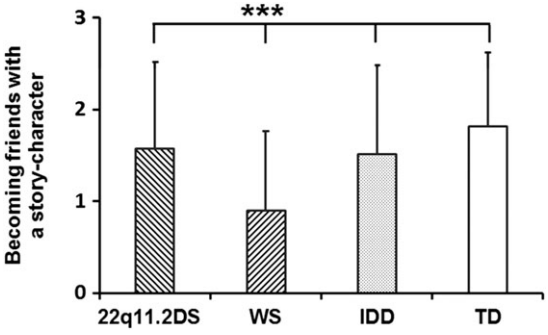

Figure 3 Becoming friends with a story character. Children with Williams syndrome (WS) were more willing to become friends with a story character even when the character's motives were negative (i.e. they scored poorly in this question compared with the rest of the groups). Error bars depict standard deviation. Mean ± SD: WS: 0.90 ± 0.73 < TD: 1.82 ± 0.37, 22q11.2DS: 1.58 ± 0.57, idiopathic developmental disability: 1.52 ± 0.69; $^{***}P < 0.001$.

labelling different facial stimuli as happy) was similar to that of other groups. Because it is easier to identify 'happy face' based on specific parts of the face as compared with other emotions (Calder *et al.* 2000), our results are consistent with studies showing that individuals with WS focus on specific parts of the face rather than on it entirely (Tager-Flusberg *et al.* 2003). Indeed, findings emerging from brain imaging studies further suggest that the brain activity of individuals with WS vs. TD is altered during face processing tasks, with happy faces inducing greater right amygdala activation and fearful faces inducing lower overall amygdala activation (Haas *et al.* 2009).

Additionally, the WS group demonstrated intact ability to label facial stimuli but poor ability to match the same stimuli, compared with TD controls. Their performance in the labelling module can be explained by their relative verbal proficiency and their tendency to rely on verbal descriptors for this matter (Brock *et al.* 2007; Vivanti *et al.* 2016). Their poor performance in the matching module is likely to be explained by their disrupted visuospatial capacity (Bellugi *et al.* 1994). In 22q11.2DS, the poor face recognition ability may be sub-served by their difficulty to process facial configurations as a unified, *gestalt*-like, unit (Glaser *et al.* 2010), coupled with disruption in sub-cortical regions responsible for face processing, including the superior temporal sulcus and the amygdala (Johnson 2005; Pessoa and Adolphs 2010; Drew *et al.* 2011; Leleu *et al.* 2016).

In the false belief tasks, a different pattern emerged; individuals with WS and IDD performed relatively well, but worse than individuals with 22q11.2DS and TD controls (Porter *et al.* 2008). A plausible explanation is that false belief involves several cognitive functions – such as perceptual and auditory processing, working memory and executive control – all of which are abnormal in WS (Meyer-Lindenberg *et al.* 2005; Porter *et al.* 2007; Zarchi *et al.* 2015).

When asked to identify situations where positive emotions were concealed by negative ones, the three clinical groups performed below par compared with TD controls. This pattern replicated also when real-negative emotions were concealed by apparent-positive emotions, except that 22q11.2DS performed comparably well with TD in this condition. The poor performance of individuals with WS in both conditions parallels their difficulty to identify others' concealed intentions and thoughts, which often prevents them from developing alarming signals when they face potentially harmful circumstances (Riby *et al.* 2014). Children with 22q11.2DS performed relatively well when asked to recognise negative emotions concealed by positive ones. A possible explanation for that may be nested in their anxious temperament and their innate bias towards negative social cues (Azuma *et al.* 2015).

Limitations

Limitations of the current study may include the relatively small sample size of each group, the fact that two stimuli from the emotion recognition task were omitted after TD participants did not recognise them adequately and the lack of reliable diagnostic instruments – such as the Read the Mind in the Eyes Test (Baron-Cohen *et al.* 2001) or the Interpersonal Reactivity Index (Davis 1980) – to assess autistic characteristics among enrolled children.

In addition, the absence of an ASD group to serve as an additional control group for the genetic syndromes is a methodological caveat of the current study that merits future research. The importance of contrasting the syndromes with an ASD group is strengthened given the well-characterised neurodevelopmental deficits in ASD (despite the lack of clear genetic loci) and initial findings showing fundamental discrepancies in some socio-cognitive abilities between ASD, 22q11.2DS and WS (McCabe *et al.* 2013; Vivanti *et al.* 2017a; Vivanti *et al.* 2017b).

Future research into social cognition in children with Williams and 22q112.DS is recommended to endorse the points previously mentioned when aiming to highlight syndrome-unique, syndrome-shared and neurodevelopment-shared socio-cognitive abilities of affected individuals. Moreover, the fourth behavioural task that was employed (which included social scripts) suggests that stories may be a prolific manner to expose children with WS to different social circumstances and to train them how to respond in potentially harmful situations (to reduce their risk of being abused).

Conclusions

The multi-task broad battery of abilities employed here enabled us to expose strengths and weaknesses in several socio-cognitive domains that are either

specific to one of the syndromes, shared between the syndromes or shared between the three clinical (intellectual disabilities) groups compared with controls. Together with the existing literature, our findings support the development of age-appropriate and condition-appropriate clinical evaluation practices and intervention approaches that are geared towards alleviating the suffering of affected individuals and their families.

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Conflict of Interest

The authors declare having no conflict of interest.

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