Research Report:

Can individuals with Williams syndrome interpret mental states from moving faces?

Deborah M Riby
School of Psychology, Newcastle University

Elisa Back
Psychology Research Unit, Kingston University London

Address for correspondence: Dr. Deborah Riby, School of Psychology, Ridley Building, Newcastle University, Newcastle upon Tyne, NE1 7RU, England, UK. Tel: +44 (0)191 222 6556. Email: D.M.Riby@ncl.ac.uk
Abstract

The Williams syndrome (WS) social phenotype is characterised by a high level of social engagement, heightened empathy and prolonged attention to people’s faces. These behaviours appear in contradiction to research reporting problems recognising and interpreting basic emotions and more complex mental states from other people. The current task involved dynamic (moving) face stimuli of an actor depicting complex mental states (e.g. worried, disinterested). Cues from the eye and mouth regions were systematically frozen and kept neutrally expressive to help identify the source of mental state information in typical development and WS. Eighteen individuals with WS (aged 8-23 years) and matched groups of typically developing participants were most accurate inferring mental states from whole dynamic faces. In this condition individuals with WS performed at a level predicted by chronological age. When face parts (eyes or mouth) were frozen and neutrally expressive, individuals with WS showed the greatest decrement in performance when the eye region was uninformative. We propose that using moving whole face stimuli individuals with WS can infer mental states and the eye region plays a particularly important role in performance.

Keywords: Williams syndrome, facial expression, mental states, social cognition.
Can individuals with Williams syndrome interpret mental states from moving faces?

In a social environment it is critical that we have the skills for successful interpersonal communication to allow smooth running interactions with the people around us. One skill that is particularly important is the ability to interpret information from the faces of our companions. The human face provides a wealth of information that is central to social communication (Haxby, Hoffman, & Gobbini, 2000). The face provides cues to identity, the importance of which is emphasised by the social interaction difficulties experienced by individuals with prosopagnosia (e.g. Yardley, McDermott, Pisarski, Duchaine, & Nakayama, 2008). Equally important are communicative signals; such cues provide insights into emotions, thoughts and intentions that must be interpreted to allow us to adapt our behaviour appropriately. Individuals with some neuro-developmental disorders have problems interpreting communicative signals from faces, which may in turn have implications for social interaction styles. One such case is the genetically based neuro-developmental disorder Williams syndrome.

Williams syndrome (WS) has a prevalence of 1 in 20,000 and is caused by a micro-deletion of approximately 25 genes on chromosome 7 (7q11.23; Korenberg et al., 2000). There has been a recent surge of interest in the social phenotype associated with WS and the nature of social interaction styles. The WS social profile is characterised by a strong interest or even propulsion towards social engagement (Jones et al., 2000; Frigerio et al., 2006). In research exploring the personality characteristics of children with WS, Klein-Tasman and Mervis (2003) found that the majority of children with the disorder (96% of their sample) showed behaviours associated with being ‘people-oriented’ and ‘sensitive’. The WS social profile is clearly very different to that associated with functioning on the autistic spectrum, although
social behaviour in neither group can be considered ‘typical’ (Brock, Einav, & Riby, 2008). Researchers have been particularly interested in the role of the face in the social approach style of individuals with WS. Social interest may manifest itself as intense attention towards human faces with prolonged face gaze (Mervis et al., 2003; Riby & Hancock, 2008, 2009), high levels of empathy toward people in distress (Tager-Flusberg & Sullivan, 2000) and an increased tendency to rate unfamiliar people as highly approachable (Jones et al., 2000). It is widely reported that individuals with WS rate unfamiliar faces as approachable that typically developing individuals would deem unapproachable (see Frigerio et al., 2006; Jones et al., 2000) and this type of behaviour has been referred to as atypical social approach. Researchers have made an explicit link between the types of approach behaviour used by individuals with WS and their interest in attending to faces of other people. Recent research has suggested that such behaviours are unlikely to be due to ‘social stimulus attraction’ (Frigerio et al., 2006). There is little evidence that faces capture attention in an abnormal manner (Ribi & Hancock, 2009). Rather, such behaviours have been linked with frontal lobe impairment and poor social response inhibition (Porter, Coltheart, & Langdon, 2007). Indeed frontal lobe impairments are likely to contribute not only to the social behaviours that typify the disorder but also extrapolate to the cognitive phenotype of WS (Rhodes, Riby, Park, Fraser, & Campbell, in press).

Given the highly social behaviours that are associated with WS, alongside claims of empathetic behaviour and an interest in attending to faces, it might be predicated that WS individuals would perform well on tasks involving expression perception. However, in studies of explicit emotion recognition ability, researchers have repeatedly found deficits and performance at a level characteristic of individuals with other forms of intellectual disability (Gagliardi, Frigerio, Burt, Cazzaniga, Perrett, & Borgatti, 2003; Plesa Skwerer et al., 2006a;
Plesa Skwerer, Verbalis, Schofield, Faja, & Tager-Flusberg, 2006b). When discriminating basic expressions of emotion from schematic faces (happy, sad), children with WS perform at a level comparable to mental age matched typically developing children (Karmiloff-Smith et al., 1995, exp. 1), even when completing a task designed for much younger individuals. Slightly more complex tasks, such as sorting faces based on emotional expressions (Tager-Flusberg & Sullivan, 2000, exp. 3) and recognising expressions of emotion from dynamic faces (Gagliardi et al., 2003) prove even more challenging. Finally Porter, Coltheart, and Langdon (2007) report that individuals with WS perform at a level comparable to mental (rather than chronological) age when recognising emotions (happy, sad, angry, scared) from faces, voices and body postures. All these tasks have focused on perception of the six basic emotions: happiness, sadness, fear, anger, surprise and disgust (Ekman, 1993). Claims of empathetic behaviour appear not to be entwined with strength at interpreting these basic facial expressions.

More complex emotions (those of the ‘non-basic’ variety) can be considered as ones that involve cognitive parameters alongside the physiological correlates of basic emotions (see Zinck & Newen, 2008 for discussion). Examples include: worried, disinterested, jealous, amongst many others. The ability to ascribe such ‘mental states’ to others based on facial depictions of complex emotions is considered key to understanding others’ minds (see Zinck, 2008). Together the ability to ascribe mental states (‘basic mentalising’) and the more complex skill of verbally attributing propositional attitudes to another person (‘theory of mind’) allow sophisticated interpersonal interactions and social understanding (Zinck, 2008). Real life social communication rarely relies solely upon basic expressions of emotion and often involves a range of much more complex mental states. The interpretation of complex emotional or mental states has been found to be problematic for individuals with some neuro-
developmental and clinical disorders (e.g. autism, Baron-Cohen, 1995; schizophrenia, Kington, Jones, Watt, Hopkin, & Williams, 2000). Difficulties interpreting such cues are likely to be central to observed social communication styles. There have been a small number of previously published studies exploring the interpretation of complex mental states by individuals with WS.

In an exploration of socio-perceptual (basic mentalising) skill, Tager-Flusberg, Boshart and Baron-Cohen (1998) assessed how well adults with WS could label photographs of faces depicting complex mental states. The task was derived from the ‘Reading the Mind from the Eyes’ assessment (Baron-Cohen, Wheelwright, & Jolliffe, 1997) where only the eye region was available for viewing. The stimuli showed a strip of the face that included the eyes and were presented in black & white. This task has been widely applied to participants with autistic spectrum disorders (e.g. Baron-Cohen et al., 1997; Baron-Cohen, Wheelwright, Hill, Raste & Plumb, 2001) and has also been used with patients who have amygdala dysfunction (Adolphs, Baron-Cohen & Tranel, 2002). The task used by Tager-Flusberg and colleagues (1998) involved WS participants deciding which mental state was depicted in the eye region of the face stimuli (e.g. disinterested, worried). Participants were required to choose between two semantically opposite (for example sympathetic / unsympathetic) target descriptions for each trial (50% chance). Adults with WS (n=13) were compared to another population with reported social deficits; namely Prader-Willi syndrome. Although individuals with WS performed more accurately than those with Prader-Willi syndrome only 6 of the 13 participants scored within a range predicted by age-matched typically developing individuals. The authors suggested that their study illustrated a relative ‘sparing’ of the cognitive capacity to mentalise, however the choice of comparison group, number of mental states and participants numbers make generalisations from this study somewhat difficult. The ‘Reading
the Mind from the Eyes’ task was revised in 2001 (Baron-Cohen, Wheelwright & Hill, 2001) and that version of the task, using four options for each answer and being more sensitive to subtle deficits of mental state perception, was used with a larger sample of individuals who had WS (n=43). Plesa Skwerer and colleagues (2006) tested adults with WS who were compared to typically developing individuals and those with intellectual difficulties. The same participants completed the mental state task alongside a task involving moving faces for the interpretation of more basic emotional expressions. In Experiment 1 where participants interpreted mental states from the eye region, participants with WS performed at a level comparable to individuals with intellectual difficulties. In Experiment 2 where participants recognised basic expressions (happy, sad, fearful, angry, disgust, surprise) from moving faces shown in 5 second movie clips, individuals with WS again performed at a level comparable to their mental age. The authors concluded that when interpreting both basic expressions of emotion and more complex mental states individuals with WS perform at a level predicted by their mental (rather than chronological) age.

There is a clear difference between the performance levels reported by Plesa Skwerer et al. (2006b; Experiment 1) and Tager-Flusberg et al. (1998) for the interpretation of mental state information. This difference is likely to relate to changes in procedures between studies (e.g., number of mental states assessed, number of answer options, sample size, choice of comparison group). The importance of adapting task design has also been shown by the fact that deficits inferring mental states from the eyes by individuals on the autistic spectrum have failed to be replicated across tasks that vary the procedures and stimuli that are used (e.g., Back, Ropar, & Mitchell, 2007; Ponnet, Roeyers, Buysse, de Clercq, & van der Heyden, 2004). Importantly, changing the task requirements will inherently change the way that information is perceived and processed.
Relating to the previously reported behavioural performance, researchers have also attempted to pinpoint the neuropsychological underpinnings of social behaviour and emotional understanding in WS. Neuropsychological evidence has suggested that amygdala impairment may play a central role in the emotion deficits associated with WS (e.g. Martens, Wilson, Dudgeon, & Reutens, 2009). It is well recognised that the amygdala is critical to the perception of facial expressions (Adolphs, Tranel, Damasio, & Damasio, 1994) and individuals with amygdala damage have difficulty interpreting complex emotions from the eye region on the ‘Reading the Mind from the Eyes’ task (Adolphs et al., 2002). Individuals with WS also show abnormalities of amygdala structure and function (Haas, Mills, Yam, Hoeft, Bellugi, & Reiss, 2009). The role of the amygdala in the social phenotype associated with WS has attracted a great deal of attention (e.g. Jawaid, Schmolk, & Schulz, 2008; Martens et al., 2009; Jawaid, Riby, Egridere, Schmolck, Kass, & Schulz, in press). Research has considered how behaviours that are associated with the WS social phenotype relate to the behaviours shown by individuals with amygdala damage. It is recognised that adults with acquired amygdala damage also give abnormal social approach ratings to faces (e.g. Adolphs et al., 1994). However, Porter and colleagues (2007) have emphasised that on emotion recognition and social approach tasks individuals with WS do not replicate the pattern seen by individuals with acquired amygdala damage. Similarly, Frigerio and colleagues (2006) reject the notion that amygdala dysfunction causes abnormal social approachability ratings, in favour of the idea that individuals with WS have heightened ‘social drive’. However, Meyer-Lindenberg, Mervis and Berman (2006) have showed abnormal amygdala-prefrontal connectivity in WS using fMRI. When individuals with the disorder attended to angry and fearful facial expressions they elicited reduced amygdala activation compared to typically developing individuals. Similarly, Plesa Skwerer and colleagues (2009) assessed involvement
of the amygdala through measurement of galvanic skin response, an amygdala-mediated measure (see Adolphs, 2001). Whilst attending to short movie extracts of actors presenting emotional expressions (happy, sad, fear, angry, disgust, and surprise), individuals with WS exhibited hypo-arousal compared to individuals with other forms of developmental delay. This hypo-arousal occurred alongside emotion recognition performance at the level predicted by mental age. Plesa Skwerer et al. (2009) concluded that their findings supported the notion of amygdala dysregulation and problems with connectivity to other brain regions involved in socio-emotional processing (e.g. orbitofrontal, medial prefrontal regions). Interestingly, hypo-arousal has also been found for individuals with WS during one-to-one interactions (Doherty-Sneddon et al., 2009), rather than attending to images on a computer screen. Therefore, evidence for the exact nature of amygdala dysfunction and its’ role in emotion perception (and the wider WS social phenotype) remains unclear but is highly likely to be a key candidate for understanding the neural underpinnings associated with social behaviours and socio-emotive skills in WS.

We have emphasised the need to look at faces during social interactions to allow deciphering of subtle cues of thoughts or feelings. Typically developing adults and children show a preference for looking at the eyes and mouths of human faces as these regions convey important information (Martens, Siegmund, & Grusser, 1993). The results of research assessing mentalising capacity for individuals with autistic spectrum disorders (ASD) has focused on the role of processing information from the eye region. It is recognised that individuals with autistic disorder are less proficient at processing information from the upper face region, including the eyes (e.g. Langdell, 1978; Riby, Doherty-Sneddon, & Bruce, 2009). Additionally, eye tracking research suggests that individuals on the autistic spectrum show reduced spontaneous allocation of attention to the upper region of faces (Ripy &
Hancock, 2008). Together such findings are used to suggest that inattention to the upper face/eye region throughout development is likely to contribute to problems inferring information from that region, for example mental states. Eye tracking research involving individuals with WS has also shown that this group allocates spontaneous attention to the upper face region atypically. However, the pattern of gaze is very different to that seen in ASD as atypically prolonged gaze (rather than reduced gaze) is allocated the eyes (Riby & Hancock, 2008).

When attending to faces showing basic emotional expressions (neutral, happy, angry, fear) individuals with WS spend a larger proportion of their face gaze fixating on the eye region and other salient facial features (e.g. mouth, nose) than individuals developing typically (Porter, Shaw, & Marsh, in press) who distribute their fixations throughout the entire face. If the eye region is particularly important to mentalising capacity (as assessed by the previously detailed tasks) then it could be predicted that attention to this region would aid or even enhance performance for individuals with WS, in a manner very different to that seen for individuals on the autistic spectrum. However, the previously mentioned tasks assessing emotion and mental state processing by individuals with WS have not suggested enhanced sensitivity in this disorder group, irrespective of the increased allocation of attention to the eyes. As the eye region plays a more important role in the interpretation of mental states than basic emotions (Baron-Cohen et al., 1997), further research is required to understand the role of the eye region (within the whole face) for the interpretation of mental states by individuals with WS.

Although a small number of studies, previously mentioned, have used moving faces in emotion recognition tasks (e.g. Gagliardi et al., 2003; Plesa Skwerer et al., 2006b), none to date have used moving faces for the interpretation of mental state information by individuals with WS. The mental state assessments utilised so far have been dominated by static black
and white stimuli showing just the eye region, which reduces the ecological validity that we encounter during more natural social interactions. In typical development, moving whole face stimuli have been found to aid performance in numerous types of tasks; for example face memory and learning (Lander & Bruce, 2003), the recognition of some basic emotions (sad, angry; Harwood, Hall, & Shinkfield, 1999) and importantly mental states (Back, Jordan & Thomas, 2009). Back and colleagues (2009; Experiment 1) found that the performance of typically developing adults on a mental state recognition task (e.g. using mental states such as anxious, disapproving, and relieved) was aided by the use of dynamic whole face stimuli. The task had the benefit of also using more naturalistic whole face images as opposed to cropped depictions of the eye region. When the researchers selectively froze face regions so that a particular region remained static and neutral (eyes, mouth, nose; Experiment 2), typically developing adults were especially hindered at recognising mental states when the eye region was frozen (considering, disinterest, doubtful, flirtatious, relieved, surprised) and also when the mouth was frozen (anxious, considering, relieved, surprised). These findings suggested that movement throughout the face is important for the detection of mental state information yet freezing the eyes had a detrimental effect across more mental states than freezing the mouth, emphasising their role in mental state detection. Although the addition of dynamic information has not been found to aid the recognition of basic emotions in WS (Gagliardi et al., 2003; Plesa Skwerer et al., 2006b), a task that investigates mental state inferences from dynamic faces has not previously been applied to this population.

The present study builds upon existing knowledge of the socio-perceptual skills associated with WS and assesses the ability to recognise mental states from dynamic whole faces and dynamic faces with either the eye or mouth region frozen. This investigation will allow us to assess how well individuals with WS can infer mental states using an established task that has
not only been applied to typical development (Back et al., 2009) but has also been used with individuals with another neuro-developmental disorder, autism (Back et al., 2007). Findings from the study by Back et al., (2007) suggest that individuals with autism can use the eyes when inferring mental states and that they are just as successful as typically developing children when attributing mental states to exclusively the eyes. Importantly, in the present task for the whole face condition participants will be able to gain cues from all facial regions and this may aid performance on such tasks for individuals with WS who may have difficulty using isolated, unnatural, cropped face parts. By systematically freezing the eye or mouth regions to keep them neutrally expressive it will be possible to explore the relative contribution of these facial regions for the inference of mental state information, in comparison to the role played by these regions in typical development. As the upper face is particularly salient in typical development and WS (e.g. Riby et al., 2009), it is predicted that freezing the eye region will be detrimental to performance in both groups. It remains unclear whether the relative contribution of facial regions for inferring mental states will differ between typically developing participants and those with WS. However, we hypothesize (based on previous research exploring the allocation of attention to the eye and mouth regions, Riby & Hancock, 2008; Porter et al., in press) that for individuals with WS, freezing the eyes will cause a more severe decrement to performance than freezing the mouth. Interestingly, research has illustrated that removing information from the eye region (by covering the eyes with sunglasses) has a more detrimental impact upon facial identity matching ability for individuals with WS than those developing typically (Ribu, in press). We extrapolate here to the investigation of mental state interpretation and explore involvement of the eye region.

Method
Participants

Eighteen individuals with WS were recruited through existing links with the Williams syndrome Foundation in the UK and all participants were involved in other ongoing studies.

The participants ranged from 8 years 6 months to 23 years 6 months (mean 13 years 8 months). All participants had previously been clinically diagnosed and also had their diagnosis confirmed with positive fluorescent in situ hybridisation (FISH) testing to detect the deletion of the ELN gene on the long arm of chromosome 7. The sample was comprised of 8 female and 10 male participants. Participants with WS were individually matched to three typically developing participants of comparable: i) nonverbal ability (NV) using the Ravens Coloured Progressive Matrices task (RCPM: Raven, Court, & Raven, 1990; max score 36) ii) verbal ability (V) using raw score on the British Picture Vocabulary Scale II (BPVS II; Dunn, Dunn, Whetton, & Burley, 1997) and iii) chronological age (CA). All participant pairs were also matched on gender. Typically developing participants complied with inclusion criteria by scoring within the ‘normal’ behaviour range on the Strengths & Difficulties Questionnaire and therefore indicating the absence of difficulties in the areas of emotions, conduct, hyperactivity, peer relationships or pro-social behaviour (SDQ; total difficulties scores between 0-11; Goodman, 2001). The SDQ was completed by class teachers.

Table 1 summarises the participant characteristics for all groups. Importantly individuals with WS did not differ from the nonverbal (NV) group on the basis on RCPM score ($p = .36$), they did not differ from the verbal (V) matched group on the BPVS raw score ($p = .44$) and they did
not differ from the chronological age (CA) matched group on the basis of age ($p=.61$).

Informed consent was received for all participants prior to their involvement in the research. Before recruitment began the research was approved by the relevant Ethics Committees.

Insert Table One

Stimuli

The stimuli were those previously used by Back and colleagues (2007) to assess mental state interpretation ability for individuals with autistic spectrum disorders. Further details about the development of the stimuli (including the full validation procedures, pilot testing and stimuli examples) and methods can be obtained from Back et al. (2007; 2009). See Back et al. (2007) for a full list of foils used for each mental state. One actor was used to depict all mental states, exactly replicating the previous research using these stimuli and procedures. Examples of the stimuli can be found at [http://www.psychology.nottingham.ac.uk/staff/lpxeb](http://www.psychology.nottingham.ac.uk/staff/lpxeb).

The dynamic colour stimuli consisted of eight mental states (deciding, don’t trust, disapproving, not interested, not sure, relieved, surprised, and worried), each of which was presented in three different display types (whole dynamic face, frozen eyes, and frozen mouth). The duration of each movie clip was 7 seconds, moving from neutral to fully expressive and returning to neutral. In the eye and mouth frozen conditions ‘freezing’ techniques had been applied to the stimuli so that motion was frozen (e.g. static with a neutral expression) in that region (eyes or mouth) while the rest of the face moved to develop the desired expression. Therefore, freezing the eye and mouth regions varied the amount of dynamic information available for mental state interpretation.
All stimuli were inserted as QuickTime clips into a PowerPoint presentation and a Dell Latitude D820 laptop computer was used for stimuli presentation. Throughout the task the stimuli were presented in a different random order across participants. In total the participant viewed each stimulus twice with the answer list randomised across presentations. Therefore there were a total of 48 trials (16 dynamic, 16 frozen mouth, and 16 frozen eyes). After the presentation of stimuli, participants were shown a list of four possible mental states (one correct answer plus three incorrect foils). The experimenter read loud the words for all participants that appeared simultaneously on the screen. The experimenter manually recorded the verbal response for each trial and scored task accuracy.

Procedure

Prior to the experiment, the mental states (those detailed above) and the foils were read aloud to participants in context to ensure an appropriate level of understanding (see Back et al. 2007) and to give participants the opportunity to ask about any of the words / descriptions used in the task. The study was introduced to participants who sat in front of the laptop computer to attend to the stimuli and listen to task instructions. Participants were told that ‘There will be lots of faces appearing on the screen in front of you, please look at each face carefully. After each face four words will appear on the screen; please choose the word that best describes what the person was thinking or feeling and say it out loud’ (replicating the instructions used by Back and colleagues (2007) for individuals with autistic spectrum disorders). Participants started with a practice trial to ensure they understood the instructions and task procedure. As previously detailed, after each clip the participant was presented with 4 possible mental state labels (both on screen and read aloud by the experimenter) and they made their response to the experimenter. The task was self-paced and the answer options
remained on screen until a response was provided (each clip was only shown once per trial). No feedback was provided during the experiment. At the end of the experiment all participants were thanked for their time.

Results

Accuracy scores for inferring mental states from the different display types in the WS and control groups (NV, V, CA) were explored using a three-way ANOVA (mental state x display type x group). This revealed no main effect of mental state, $F(7,476)=1.63$, $p=.125$, $n^2=.023$ (note that this may indicate a trend towards significance that may have been more robust with an increase in sample size). Looking at the mean performance of the WS group and all typically developing participants ($n=54$) in just the full face dynamic condition, there was some variability between mental states, although care is required exploring this non-significant effect. In the WS group (also show in Figure 1) highest accuracy was seen for ‘not sure’ (mean 69%) and lowest accuracy is found for ‘don’t trust’ (mean 50%). Difficulty inferring the mental state ‘don’t trust’ was also the least accurate for the typically developing group (when considering all typically developing participants as one sample; mean 50%). For the typically developing sample the mental state inferred with greatest accuracy was relieved (mean 63%).

There was a main effect of display type, $F(2,136)= 133.19$, $p<.001$, $n^2=.662$ where t-tests showed that participants were most accurate at inferring mental states from the dynamic whole face than when either the eyes were frozen, $t(71)=11.87$, $p<.001$ or when the mouth was frozen, $t(71)=10.10$, $p<.001$. Moreover, freezing the eyes resulted in lower accuracy scores than freezing the mouth, $t(71)= 3.61$, $p=.001$. Interestingly, there was a main effect of
group, $F(3,68)=48.98, p<.001, np^2=.684$ and post-hoc tests (Tukey HSD) revealed that all groups significantly differed in accuracy scores ($p<.001$) with the exception of the matched verbal age group and WS group ($p>.05$). As indicated in Table 2, the mean scores for each group (collapsed across mental state and display type) are as follows: 64% for the CA group, 50% for the V matches, 46% for WS, and 37% for NV matches. See Figure 1 for the breakdown of mental state and presentation style for the WS group.

Insert Table Two

There was also a significant interaction between display type and group, $F(6,136)=11.45, p<.001, np^2=.336$. This interaction was unpacked using t-tests and this revealed that all groups performed significantly better on the whole dynamic face compared to the eyes frozen and mouth frozen conditions ($p<.01$). Importantly, only the WS group had significantly lower accuracy rates when the eyes were frozen compared to when the mouth was frozen indicating that individuals with WS rely especially on the eyes rather than the mouth when inferring mental states from faces, $t(17)=6.93, p<.001$, and showing more reliance on the eyes than individuals developing typically.

Insert Figure 1

The interaction between display type and group can also be explored by investigating the performance for each display type with a one-way ANOVA with factor Group. This revealed that for the whole dynamic face condition there was a significant difference between groups $F(3,71)=12.41, p<.001$. Individuals with WS performed at a level comparable to the chronological age matched group (between groups $p>.05$), showed a possible trend for increased performance in relation to verbal ability matches, $t(17)=1.93, p=.07$, and performed
significantly better than the nonverbal matches, $t(17)=4.61, p<.001$. With the eye region frozen there was a significant effect of Group, $F(3,71)=79.29, p<.001$, individuals with WS performed significantly less accurately than the chronological age matches, $t(17)=14.11, p<.001$, the verbal ability matches, $t(17)=16.12, p<.001$ and the nonverbal matches $t(17)=15.42, p<.001$. Finally, for the frozen mouth trials there was also a significant effect of Group, $F(3,71)=29.26, p<.001$. Individuals with WS performed significantly worse than the chronological age matched group, $t(17)=4.53, p<.001$. There was a non-significant trend for the verbal matches to perform better than the WS group, $t(17)=1.87, p=.07$ and a trend in the same direction for the nonverbal matches, $t(17)=2.03, p=.08$. These patterns are evident in the mean performance levels shown in Table 2. No other interactions were significant (all $Fs<.842$, all $ps> .753$).

The relationship between mental state interpretation and participant characteristics

Although some care is required due to the small sample size of the WS cohort, we conducted a Pearson’s correlation to explore the relationship between overall task performance (across all mental states and presentation styles) and i) chronological age, ii) verbal ability (raw score on the BPVS) and iii) non-verbal ability (raw score on the RCPM). We collapsed the three groups of typically developing participants into one sample for this analysis (n=54) whilst also exploring these relationships in WS (n=18). For the WS group there was a significant relationship between age and ability to infer mental states ($r=.70, p<.01$). Increased age was related to greater proficiency. Mental state interpretation ability was also significantly positively correlated verbal ability ($r=.61, p<.05$) and nonverbal ability ($r=.54, p<.05$). For typically developing participants the pattern was repeated in that increased age ($r=.64,$
verbal ability ($r=.58, p<.001$) and non-verbal ability ($r=.50, p<.001$) were all significantly correlated with increased mental state interpretation ability.

Discussion

This study assessed the ability to infer mental states from dynamic whole faces and faces where dynamic information was removed from the eyes or the mouth by keeping these regions neutrally expressive. The use of moving stimuli that systematically froze information in the eye and mouth regions was important to elucidate whether the facial features used by individuals with WS differed from typical controls. Typically developing individuals have previously been found to benefit from dynamic rather than static presentations for the inference of mental states as they include additional temporal information (Back, et al., 2009; Back, Ropar, & Mitchell, in prep). To date this task has been applied to typically developing adults (Back et al., 2009), typically developing children (Back et al., in preparation), individuals with autistic spectrum disorders (Back et al., 2007) and now individuals with WS have completed the dynamic condition of a mental state interpretation task. The current study showed that for typically developing participants as well as those with WS, when using dynamic information from faces it was easier to infer mental states from the whole face than just part of the face. Interestingly, when only part of the face showed the mental state individuals with WS showed most detriment to performance when the eye region was frozen in a neutral expression and thus uninformative (see Figure 1), but typically developing participants in the same study did not show this pattern. This cross-population comparison is particularly important and emphasises that when viewing the same stimuli groups may differ in the way that information is processed and interpreted. The finding suggests that the eyes
play a critical role in the interpretation of mental state information for individuals with WS and we tentatively suggest that they may play a more important role for this population than those developing typically. Individuals who are developing typically may utilise information dispersed throughout the face, not only the eye region. Both the eye and mouth regions together provide the most reliable source of mental state information for individuals developing typically as well as individuals with WS. It is highly likely that the changing ‘configuration’ of features throughout the face is critical to mental state interpretation. For example, when an emotion is expressed the spacing between features will change throughout the entire face (referred to as second-order relational face information, see Diamond & Carey, 1986). Participants with WS performed at a level comparable to their chronological age when the whole dynamic face was available to infer mental states and therefore these feature and configuration changes occurred throughout the whole face. However they performed less accurately than chronological matches across the task as a whole due to the inclusion of trials where only part of the face was emotionally expressive.

Performing at a level predicted by chronological age when using whole dynamic faces indicates much better ability than that shown in previous research investigating socio-perceptual capabilities (e.g. studies reporting performance at mental age capacity, Plesa Skwerer et al., 2006b). The notion of proficiency in interpreting mental states from whole moving faces appears to contradict evidence that individuals with WS have extreme problems with some forms of social functioning in their everyday lives. For example, many individuals have problems forming peer friendships and lasting relationships (e.g. Davies, Udwin, & Howlin, 1998), show deficits using relevant communication styles during interpersonal contact (e.g. Laws & Bishop, 2004) and suffer social isolation as an adult (Davies et al., 1998; see Riby, Bruce, & Jawaid, in press, for a discussion of all these issues). Although
other studies report problems inferring mental states (e.g. socio-perceptual deficits) alongside widespread evidence of everyday social functioning difficulties, the current research tentatively suggests that socio-perceptual skills are not the *sole* cause of social interaction difficulties. It could be proposed that such difficulties are the result of other components of behaviour associated with WS as well as any possible problems using socio-perceptual skills. For example, social disinhibition and problems modulating behavioural responses play an important role in social expertise. Previous research has suggested involvement of the frontal lobe in social approach atypicalities reported in WS (e.g. Porter et al., 2007). Research has also suggested that attentional and executive control deficits, as well as other neuropsychological impairments are correlated with a range of behavioural problems in WS (as assessed using parent-rated questionnaires; Rhodes et al., in press). Further research is required to make *explicit* links between socio-cognitive and socio-perceptual skills and reports of everyday behaviours. It currently remains unclear whether the social behaviours that are associated with WS are related more to problems of social-perception (although the current research moves away from this interpretation) or to other components of behaviour (such as behavioural dysregulation). Importantly it is currently difficult to accommodate divergence between reports of social behaviours (especially those derived from parent reports when those parents may be aware of the reported characteristics of WS) and performance on socio-perceptual experimental tasks. Further research is required here to involve a range of methodologies with the same individuals.

The previously conducted research in this area has been solely based on the ‘Reading the Mind from the Eyes’ task (Baron-Cohen et al., 1997, 2001) where only the eye region is available and is shown as a static black & white image. Changing the task demands and the nature of stimuli (as well as differences of participant age and sample size) will impact upon
the ability to make comparisons across studies. However, taking into consideration the difference between the level of performance indicated by Plesa Skwerer and colleagues (2006b) and that shown here for whole faces, it is clear that the additional dynamic, colour, whole face stimuli aids the interpretation of mental states in WS (and in typical development). The increased naturalistic face images that involve temporal information for the presentation of dynamic mental states is clearly beneficial for task completion and may be important for consideration when trying to teach individuals with WS (as well as those with autism, based on evidence from the same task, Back et al., 2007) to interpret complex mental states. Although the current task did not involve a static condition and therefore it is not possible to make the comparison between static and dynamic representations on mental states in WS, work with typically developing individuals emphasises the importance of temporal information in numerous face tasks. Further work on the comparison between these two conditions is therefore warranted in WS. Studies of the nature provided here can be particularly useful in devising longer-term developmental projects exploring the development of socio-perceptual skills and general social functioning abilities. Future research may be more specifically focused on adapting the type of stimuli used here into a training program for children, adolescents and adults with the disorder.

In everyday social interactions we do not encounter individuals who show different emotions expressed in the upper and lower face, or emotions restricted to one facial region. This could be confusing for individuals with WS, as well as individuals developing typically. However, previous research exploring mental state interpretation in WS has been limited to use of the ‘Reading the Mind from the Eyes’ task and therefore black & white static depictions of the eye region. We suggested that the whole face dynamic information here allows participants to access cues that they might be more likely to use in everyday social interactions with real
people. Indeed Plesa Skwerer and colleagues (2006b) emphasise that such cues are missing from their research. It may be that these cues are especially important to individuals with WS and when using such cues they are able to perform at a level comparable to their chronological (rather than mental) age. Results for the whole face dynamic condition (indicating performance at a level comparable to chronological age) suggest that this task, with increased ecological validity, is more consistent with suggestions that individuals with WS are emotionally sensitive to other people (Dykens & Rosner, 1999; Gosch & Pankau, 1997). However, the findings also need consideration alongside widely reported social deficits that accompany the disorder (e.g. peer relation and social communication difficulties, see Davies et al., 1998; Riby et al., in press). Finally, in the current study the lack of direct comparison between performance using static and dynamic stimuli with the same WS sample means that further work is required to explore whether the addition of temporal cues is as informative in this population as it is for typical adults.

Previous research applying this task has shown that individuals functioning on the autistic spectrum are able to use the eye region to infer mental states (Back et al., 2007) even though previous research had suggested otherwise (Baron-Cohen et al., 1997). The current study could be used to make similar claims regarding WS, whilst emphasising that not only do individuals with WS use the eyes but reliance upon this region is evident. Individuals with WS were the only group to show a detriment to performance when the eyes (compared to the mouth) was frozen and therefore neutrally expressive. We acknowledge that further research with a larger sample is required to investigate the trend evident in the current data when the mouth region was frozen. Research with typically developing participants and the work conducted here suggested that the mouth is important for conveying mental state information, but that the relative importance may differ in typical development and WS. If this is the case
then future research must use the most ecologically valid face stimuli as any unnatural
manipulation may create more interference for individuals with WS than those developing
typically. However, it is important to also note that similar research that has removed
information from the eye region (using sunglasses) and the mouth region (using a scarf) to
explore identity perception in WS has shown that only covering the eyes is so detrimental to
individuals with WS (Riby, in press). This suggestion also fits with other existing evidence as
it is reported that individuals with WS spontaneously attend to the eye region (but not the
mouth region) for prolonged periods of time when viewing static and moving images of
people and their faces (e.g. Riby & Hancock, 2008, 2009; Porter et al., in press). The current
study emphasises reliance upon the eye region for inferring mental states by making
information in this region uninformative. This was particularly detrimental to individuals
with WS, and this was the only group to show the large dissociation between use of the eye
and mouth regions. Typically developing participants do use information from the eyes but
also rely upon information from the rest of the face (see Back et al., 2009), for example the
mouth.

It is important that we note the ways in which the current work could be improved in future
explorations of this nature as there are a number of ways in which the results obtained here
can be taken forward. Developing the work presented here is particularly important given the
insights it has provided to our knowledge of socio-perceptual skill. The stimuli used here
were those previously applied to typical development and individuals with autistic disorder
(Back et al., 2007; 2009). However the stimuli only involved one actor depicting all mental
states. Although a thorough validation procedure took place (see Back et al., 2007) we cannot
be sure that the findings would generalize to different actors posing facial expressions for
mental states. It might be that different actors would express mental states differently as there
might be several ways of facially expressing a given mental state. It could also be proposed that since the actor's identity remains constant across trials, it is possible for more processing resources to be engaged in decoding the expressions rather than considering identity. Therefore for the results to be generalised it is important for more than one actor to be involved across mental state stimuli. On a similar point, only eight mental states were chosen for this study and in the future it would be ideal to incorporate many more (with an accompanying increase in the number of trials completed by participants). Future research may include mental states purposely designed to assess interpretations of both positive and negative emotional states. Importantly, the mental states used in the current paper were the same eight mental states that had been previously used with participants on the autistic spectrum (Back et al., 2007).

As well as modifications to the stimuli and procedure in future research there are a number of ways that exploration could tap important components of socio-perceptual skill that are not possible here, largely due to sample size. With a larger sample it would be possible to explore the impact of age and gender on mental state interpretation. The correlation analyses presented here indicate a significant increase in mental state interpretation ability with increased age (considering the full face dynamic condition). Some caution is required due to the WS sample size (n=18). It would be possible for research to explore the development of mental state interpretation with a larger sample to investigate the developmental trajectory of performance on this important socio-perceptual skill. This type of exploration could occur alongside other assessments of social functioning (using parent reports, observations of appropriate / inappropriate social encounters and experimental tasks that tap social expertise or social cognition). It would be useful to explore the development of mental state interpretation skills and also probe abilities of children and adolescents when skills are
continuing to develop. Targeting some problems as well as proficiencies that adolescents with the disorder have may allow for target training programs to aid social communication before other demands of adulthood (e.g. social independence) begin. With approximately 73% of WS adults experiencing social isolation (Davies et al., 1998) and adults with the disorder showing communication and socialization problems (Howlin et al., 1998) it is important that programs that may aid social functioning target children as early as possible.

Considering how evidence from this genetic disorder provides insights into the neural underpinnings of socio-perceptive skill, as previously noted attention has been drawn to the role of amygdala dysfunction. Individuals with amygdala damage are unable to infer mental states from the eye region using the ‘Reading the Mind from the Eyes’ task (Adolphs et al., 2002) and previous research had suggested that the same was apparent for WS (e.g. Plesa Skwerer et al., 2006b). However the current study refutes this claim with performance at a level predicted by chronological age when the whole dynamic face is available. Haas and colleagues (2009) report that compared to typically developing individuals, individuals with WS show heightened amygdala reactivity to faces showing happy expressions but reduced amygdala reactivity to negative emotions (assessed using fearful faces). In terms of accuracy to infer mental states the current task did not show a specific problem for emotions with the most negative connotations (e.g. don’t trust, disapproving, not interested). If future research was to incorporate a wider variety of both positive and negative mental states it would be possible to explore any possible dissociation in more detail. It could be proposed that if individuals with WS show reduced activation of the amygdala to negative emotions, in addition to showing increased ratings of approachability to some unfamiliar faces, then we might have expected some emotion specific deficits in the WS group. However, there was no significant effect of mental state and no interaction between the mental state and group
suggesting there were no specific emotions (from the selection used here and the available sample size) that were more or less difficult for individuals with WS compared to typically developing participants. In the results section we note that both groups had most difficulty with ‘don’t trust’ suggesting this is a particularly difficult expression to interpret even when a whole moving face is on view (50% accuracy in typical development and in WS). Given that individuals with WS show abnormalities in their tendency to approach unfamiliar people that have been judged by typical individuals with by more / less trustworthy there is an interesting avenue for further research on the evaluation of trust from faces in WS.

Although the current study did not include any direct measurement of neural mechanisms underpinning the interpretation of mental states, there are clear avenues for future investigations of this nature. It would be particularly beneficial to combine the current task or stimuli with fMRI or ERP measures (similar to Haas et al., 2009) to explore the functional importance of the social brain network in WS, especially with more ecologically valid stimuli than previously used. As well as these neuropsychological insights into mental state interpretation and the socio-cognitive network associated with WS, the current study provides a clear impetus to combine this task with eye tracking techniques to explore the distribution of attention to facial regions when individuals with and without WS make inferences about mental states. With evidence that individuals with WS show atypicalities in the spontaneous allocation of attention to faces showing basic expressions of emotion (Porter et al., in press) the inclusion of more complex mental states and dynamic stimuli is clearly warranted.

In summary, the current research emphasises that in the experimental condition that most closely matched the type of information derived from faces in everyday social situations, individuals with WS performed at a level comparable to their chronological age when
inferring mental states. When part of the face was frozen (and emotionally neutral), individuals with WS showed the largest detriment when the eyes could not be used. However, all groups showed some contribution of the mouth region when deciphering mental states. Claims of an empathetic nature during social encounters fit well with this finding. The results also suggest that problems with socio-perceptual skill may not be the sole underlying cause of social interaction and peer relationship problems in WS. We propose that in previous research exploring mental states, the use of unnatural part-face stimuli does not give an accurate interpretation of socio-perceptual skill associated with WS. When using whole face stimuli individuals with WS rely on the eyes to infer mental states.
Acknowledgements

This work was partly supported by funds from the Williams syndrome Foundation, UK, to D Riby. We would like to thank Adam Combie for helping with data collection for the participants with Williams syndrome and all individuals who took part in the research.
References


*American Journal on Mental Retardation, 104,* 270-278.


Mervis, C. B., Morris, C. A., Klein T., Bonita P., Bertrand, J. Kwitny, S., Appelbaum, L. G.,


Table 1: Participant Characteristics

<table>
<thead>
<tr>
<th></th>
<th>WS</th>
<th>NV matches</th>
<th>V matches</th>
<th>CA matches</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>C.A. *</td>
<td>13:08 (46)</td>
<td>7:01 (32)</td>
<td>10:01 (31)</td>
<td>13:09 (44)</td>
</tr>
<tr>
<td>RCPM score +</td>
<td>14 (4)</td>
<td>15 (5)</td>
<td>20 (6)</td>
<td>27 (4)</td>
</tr>
<tr>
<td>BPVS score ^</td>
<td>99 (13)</td>
<td>90 (17)</td>
<td>101 (15)</td>
<td>125 (27)</td>
</tr>
</tbody>
</table>

* Chronological age is provided as years : months (standard deviation in months)
+ Max score possible is 36 and individuals are matched on raw score
^ BPVS individuals are matched on their raw score (rather than standardised score)
Table 2: Proportion correct (standard deviation) for each Group and Presentation style as well as each Mental State (irrespective of presentation style)

<table>
<thead>
<tr>
<th>Condition</th>
<th>WS</th>
<th>NV matches $^a$</th>
<th>V matches $^b$</th>
<th>CA matches $^c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total correct</td>
<td>0.46  (.06)</td>
<td>0.37 (.04)</td>
<td>0.50 (.10)</td>
<td>0.62 (.05)</td>
</tr>
<tr>
<td>Full face</td>
<td>0.62  (.09)</td>
<td>0.49 (.07)</td>
<td>0.56 (.10)</td>
<td>0.65 (.08)</td>
</tr>
<tr>
<td>Frozen eyes</td>
<td>0.29  (.05)</td>
<td>0.43 (.08)</td>
<td>0.43 (.08)</td>
<td>0.58 (.07)</td>
</tr>
<tr>
<td>Frozen mouth</td>
<td>0.42  (.07)</td>
<td>0.47 (.11)</td>
<td>0.47 (.11)</td>
<td>0.56 (.10)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mental State</th>
<th>WS</th>
<th>NV matches $^a$</th>
<th>V matches $^b$</th>
<th>CA matches $^c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deciding</td>
<td>0.45  (.28)</td>
<td>0.35 (.22)</td>
<td>0.55 (.17)</td>
<td>0.65 (.16)</td>
</tr>
<tr>
<td>Disapproving</td>
<td>0.43  (.25)</td>
<td>0.37 (.15)</td>
<td>0.52 (.23)</td>
<td>0.65 (.22)</td>
</tr>
<tr>
<td>Not interested</td>
<td>0.47  (.26)</td>
<td>0.44 (.22)</td>
<td>0.51 (.21)</td>
<td>0.60 (.20)</td>
</tr>
<tr>
<td>Relieved</td>
<td>0.44  (.21)</td>
<td>0.42 (.17)</td>
<td>0.53 (.17)</td>
<td>0.65 (.20)</td>
</tr>
<tr>
<td>Worried</td>
<td>0.51  (.21)</td>
<td>0.34 (.16)</td>
<td>0.53 (.27)</td>
<td>0.62 (.24)</td>
</tr>
<tr>
<td>Surprised</td>
<td>0.49  (.23)</td>
<td>0.36 (.18)</td>
<td>0.46 (.21)</td>
<td>0.61 (.24)</td>
</tr>
<tr>
<td>Not sure</td>
<td>0.58  (.19)</td>
<td>0.33 (.18)</td>
<td>0.51 (.24)</td>
<td>0.57 (.21)</td>
</tr>
<tr>
<td>Don’t trust</td>
<td>0.31  (.24)</td>
<td>0.31 (.17)</td>
<td>0.44 (.21)</td>
<td>0.58 (.21)</td>
</tr>
</tbody>
</table>

$^a$ Typically developing participants matched to the WS group on nonverbal ability

$^b$ Typically developing participants matched to the WS group on verbal ability

$^c$ Typically developing participants matched to the WS group on chronological age
Figure Captions

Figure 1:

Accuracy (percentage correct) for each of the 8 mental states in each presentation condition for individuals with WS
Figure 1:

Deciding

Disapproving

Not Interested

Not Sure

Figure 1 is continued on the following page
Figure 1 continued:

- Don't Trust
- Relieved
- Surprised
- Worried