Social Processing in Williams Syndrome, Autism Spectrum Disorder and Social Anxiety Disorder

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Summary

Williams syndrome (WS), Autism Spectrum Disorder (ASD) and Social Anxiety Disorder (SoAD) are conditions which present with contrasting social profiles. With respect to social processing and social behaviour, these conditions appear to represent distinct points on a continuum, from increased social approach in WS, to social withdrawal and avoidance in ASD and SoAD. While social processing anomalies have been established across WS, ASD and SoAD, research to date has largely investigated each condition in isolation. Moreover, while it is known that individuals with these conditions display social processing abnormalities in response to emotional face stimuli, it is not known whether similar abnormalities are observed in response to biographical stimuli.

This thesis aimed to assess the influence of biographical information on social processing in individuals with WS, ASD or SoAD, using a cross-disorder comparison. A biographical learning paradigm was adapted and implemented across five papers, specifically investigating the influence of biographical information on attention allocation, emotion recognition, the salience of certain face regions and approach/avoidance decisions.

The principal findings of this thesis are as follows: 1) Biographical information influences attention allocation, with WS individuals exhibiting an attention bias for trustworthy biographical faces, while SoAD individuals display an attention bias for untrustworthy biographical faces. 2) Biographical information does not influence the direct perception of emotional expressions, however; 3) Biographical information influences the salience of the eye region of faces, with WS individuals spending more time looking at the eyes of trustworthy biographical faces, while ASD and SoAD individuals spend more time looking at the eyes of untrustworthy biographical faces. 4) Across WS, ASD and SoAD, social approach judgments are directly influenced by biographical information.

Thus, using a cross-disorder comparison, this thesis showed that biographical

information does influence social processing across WS, ASD and SoAD, largely in the direction that one would predict based on their divergent social profiles. The current thesis has contributed to the literature on social processing in WS, ASD and SoAD and provides important preliminary evidence of how biographical information may influence social processing in disorders featuring distinct social profiles.

Statement of Candidature

I, Kelsie Boulton, certify that the work in this thesis entitled "Social Processing in Williams, Syndrome, Autism Spectrum Disorder and Social Anxiety Disorder" has not been previously submitted for a higher degree to any other university or institution other than Macquarie University.

I also certify that the thesis is an original piece of research and it has been written by me. Any sources of information used throughout this thesis are acknowledged, including any help or assistance that I have received in my work and preparation of this thesis.

The research presented in this thesis was approved by the Macquarie University Human Ethics Review Committee, reference number: **5201300854**

Signed:

Kelsie Boulton (Student ID: 42018412)

September, 2018

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Thesis by Publication

This thesis has been prepared in the Macquarie University 'Thesis by Publication' format. Papers 1 through 5 have been written and prepared as independent publications. As such, there is some overlap in the literature cited and some unavoidable repetition across chapters, although I have tried to minimise this as much as possible. The formatting of the papers within this thesis generally conforms to the Publication Manual of the APA, 6th Edition, although tables and figures are inserted within the manuscripts, to assist with readability of the thesis.

General Introduction

Overview

Social perception and social knowledge (such as what we may know about a particular person, including biographical information) can influence our day-to-day responses and decisions during social interactions, often without our conscious awareness. Such information informs us of a person's identity and emotional state (Zebrowitz & Montepare, 2008), whether to attend to the person or, more specifically, to certain aspects of the person (Itier & Batty, 2009), and we also use this information in order to make social decisions such as whether to approach or avoid (Todorov, Olivola, Dotsch, & Mende-Siedlecki, 2015). Our accurate person and emotion perception and our ability to draw on salient biographical information already known about a person is crucial for social success and for survival (Adolphs, 2009). While many humans use these skills with ease, for individuals with Williams syndrome (WS), Autism Spectrum Disorder (ASD) or social anxiety disorder (SoAD), seemingly simple social interactions are fraught with difficulties (Aderka et al., 2012; Jawaid et al., 2012). Moreover, while individuals with these conditions demonstrate impairments in social perception (e.g., see Plesa Skwerer, 2017; Staugaard, 2010) , research is yet to consider whether the processing of biographical knowledge or the ability to use biographical information when responding to and making decisions of a social nature is similarly impacted. The central aim of this thesis was to investigate the influence of biographical information on attention allocation, emotion recognition, the salience of certain face regions, and approach/avoidance decisions in WS, ASD or SoAD individuals, using a cross-disorder comparison.

Williams Syndrome, Autism Spectrum Disorder and Social Anxiety Disorder

Over the past decades, WS, ASD and SoAD have attracted considerable research attention. While individuals with these conditions present with contrasting social profiles (Rapee & Heimberg, 1997; Tager-Flusberg, Plesa Skwerer, & Jospeph, 2006), they all

display abnormalities in social perception and other social processes that contribute to functional social impairments (Plesa Skwerer, 2017; Staugaard, 2010). Research to date has largely studied these conditions in isolation and different theoretical accounts have been proposed with respect to their social deficits. This general introduction provides a selective review of the theoretical accounts associated with each of the three conditions, before considering the overlap between these theories and the benefits of using cross-disorder comparisons to further our understanding of social processing and social behaviour.

Williams syndrome (WS)

WS is a rare neurodevelopmental disorder caused by a microdeletion of 25-26 genes on the long arm of chromosome 7, at location 7q.11.23 (Ewart, 1993), with prevalence rates of approximately 1 per 7,500-10,000 (Strømme, Bjømstad, & Ramstad, 2002). WS is associated with physical features (Morris & Mervis, 2000), as well as cognitive features, with many individuals displaying a mild to moderate intellectual impairment (Mervis & Klein-Tasman, 2000). Of direct relevance to the present thesis is the striking social-behavioural phenotype observed in WS, which includes an extremely friendly and hypersocial personality (Doyle, Bellugi, Korenberg, & Graham, 2004), with WS individuals known to approach others irrespective of their familiarity (Bellugi, Adolphs, Cassady, & Chiles, 1999). WS individuals also display a relative strength in face recognition abilities (Tager-Flusberg, Plesa-Skwerer, Faja, & Joseph, 2003) alongside emotion recognition impairments (Plesa Skwerer, Faja, Schofield, Verbalis, & Tager-Flusberg, 2006). They also show a strong interest in people (Jones et al., 2000) and exhibit intense eye contact (Mervis et al., 2003). This striking social-behavioural phenotype and its potential neurological and cognitive substrates has captured the interest of researchers over the past few decades. Their strengths in face processing and their sociable nature have led some authors to claim an ‘intact social module’ in WS (Karmiloff-Smith, Klima, Bellugi,

Grant, & Baron-Cohen, 1995), although this has since been refuted (Porter, Coltheart, & Langdon, 2008; Tager-Flusberg & Sullivan, 2000) .

One proposed account for the increased social interest seen in WS is the social salience hypothesis. Reflecting the anecdotal and experimental observations of increased friendliness and hypersociability in WS individuals, the social salience hypothesis suggests that social stimuli are highly salient for individuals with WS, contributing to an increased drive to approach other people (Frigerio et al., 2006). In particular, faces seem to be abnormally salient, with WS individuals spending more time looking at this area compared to neurotypical individuals (Mervis et al., 2003). This abnormal face salience begins in babies and infants with WS and continues throughout development (Jarvinen, Korenberg, & Bellugi, 2013). Eye-tracking studies indicate that WS individuals spend more time looking at faces compared to both ASD individuals and neurotypical controls (Riby & Hancock, 2009a; 2009b). Moreover, WS individuals appear to spend a disproportionate amount of time looking at the eye region of faces in comparison to neurotypical controls, as well as ASD individuals (Porter, Shaw, & Marsh, 2010; Riby & Hancock, 2008) . However, Porter and colleagues noted considerable variability within their WS sample when looking at individual face scanpaths, and this finding of increased time spent looking at the eyes has not been consistently reported across studies (Hanley, Riby, Caswell, Rooney, & Back, 2013).

Building on the literature suggesting that social stimuli, in particular, faces, are highly salient for WS individuals, a related body of research has considered the attentional mechanisms that may underpin the heightened salience for faces and increased social approach behaviours. As discussed above, eye-tracking research has revealed that individuals with WS pay an unusual amount of attention to faces, relative to both neurotypical controls and individuals with ASD. To investigate whether this increased attention appears to be selective for specific emotional expressions, researchers have

utilised visual dot-probe paradigms, where emotional (happy or angry) and neutral faces are presented simultaneously, followed by a dot appearing in the location where either the emotional or neutral face was. Participants are required to indicate the location of the dot using a button box, with faster reaction times when the dot appears in place of an emotional face indicating an attentional bias for those faces. Within the WS literature, these studies suggest that WS individuals display an attention bias for positive (happy) faces, compared to both neurotypical controls and individuals with Down Syndrome (Dodd & Porter, 2010; Goldman, Shulman, Bar-Haim, Abend, & Burack, 2016). Such findings suggest that abnormal attention patterns for faces, particularly those that are positively valenced, may contribute to the WS social phenotype.

Given findings from eye-tracking paradigms, where WS individuals spend more time fixating on faces and eyes compared to neurotypical controls, alongside findings from dot-probe paradigms, where WS individuals display attentional biases for happy expressions compared to neurotypical controls, researchers have investigated whether faces (eyes) capture the attention of WS individuals, or, in contrast, whether WS individuals experience difficulties disengaging their attention from faces, in particular, from eyes. On the whole, evidence from studies using eye-tracking paradigms suggests that the abnormal attention to faces (and eyes) seen in WS is better explained by difficulties with attentional disengagement. That is, individuals with WS do not attend to faces or eyes more quickly than neurotypical controls, but once faces or eyes have been fixated upon, WS individuals appear to spend longer looking at them compared to both neurotypical controls and individuals with ASD, as though their attention has become ‘stuck’ (Porter et al., 2010; Riby & Hancock, 2009; Riby et al., 2011) . Further, evidence from studies using the dot-probe paradigm suggests that when attentional biases of WS individuals are compared to those of neurotypical controls, the attentional bias for positive (happy) faces seen in WS individuals is at least partially driven by difficulties disengaging attention from happy

faces (Dodd & Porter, 2010; McGrath et al., 2016), consistent with eye tracking research. However, more recent applications of the dot-probe paradigm suggest that attentional disengagement difficulties may not always drive the attention biases for happy faces in WS individuals (Goldman et al., 2016), which may reflect the clinical heterogeneity within this disorder (Porter & Coltheart, 2005).

Interestingly, the increased interest in faces and eyes seen in WS individuals does not correspond to better emotion recognition abilities. In general, emotion recognition abilities in WS individuals are poorer than would be expected based on their chronological age and are instead largely commensurate with their developmental level (Gagliardi et al., 2003; Plesa Skwerer, Faja, et al., 2006; Plesa Skwerer, Verbalis, Schofield, Faja, & Tager-Flusberg, 2006). Of note, WS individuals appear to display specific difficulties when identifying neutral faces compared to both ASD individuals and same-age neurotypical controls (Jarvinen, Ng, Crivelli, Neumann, et al., 2015). In keeping with the attention bias towards happy faces reported above, recognition of happy faces does not seem to be impaired in WS (Little et al., 2013; Plesa Skwerer, Faja, et al., 2006). Moreover, WS individuals tend to misclassify other emotional expressions (angry, fearful) as happy more often than neurotypical controls (Plesa Skwerer, Verbalis, et al., 2006), as well as misclassifying emotional expressions (happy, sad, scared) as angry less often than neurotypical controls (Porter, Coltheart, & Langdon, 2007).

Based on the similarities between individuals with WS and patients with bilateral amygdala damage, who display indiscriminate approach tendencies for unfamiliar others (Adolphs, Tranel, & Damasio, 1998), a substantial body of research has explored the role of the amygdala in WS social approach. Indeed, there is evidence that WS individuals provide abnormally high approach ratings for unfamiliar faces relative to neurotypical controls (Bellugi et al., 1999; Martens, Wilson, Dudgeon, & Reutens, 2009). Moreover, Martens and colleagues found that elevated approach judgments for negative faces (faces

that had been rated as high on perceived untrustworthiness by neurotypical individuals) were associated with increased right amygdala volumes (Martens et al., 2009). In line with these structural abnormalities, WS individuals also display functional abnormalities in this brain region. When completing face matching tasks, WS individuals show decreased amygdala reactivity to threatening (angry and fearful) faces, alongside increased amygdala reactivity to positive (happy) faces (Haas et al., 2009; Meyer-Lindenberg et al., 2005; Mimura et al., 2010). It is plausible that the increased attention for positive faces and hypersociability seen in WS is related to these amygdala abnormalities. However, amygdala dysfunction is unlikely to fully account for the WS social phenotype. Behavioural findings indicate that WS individuals take emotional valence into consideration when making approach judgments, judging positive (happy) faces as more approachable than negative (angry) faces (Frigerio et al., 2006; Porter et al., 2007), a pattern of responding that would not be expected if amygdala dysfunction alone was responsible for the WS social profile.

Frontal lobe dysfunction has also been proposed as a likely contributing factor to the increased social approach behaviours seen in WS individuals. Individuals with WS fail to activate critical frontal brain regions when completing face matching tasks (Meyer-Lindenberg et al., 2005) and, compared to neurotypical controls, WS individuals display reduced frontal activation during response inhibition tasks (Mobbs et al., 2007). Moreover, neuropsychological findings suggest executive functioning deficits in this group (Hocking, Reeve, & Porter, 2015; Rhodes, Riby, Park, Fraser, & Campbell, 2010). Related to these executive functioning deficits, Porter et al. (2007) proposed that disinhibition relating to frontal abnormalities may account somewhat for the heightened approach observed in WS. Recent behavioural findings support Porter et al.'s proposal, with response inhibition impairments significantly related to increased social approach judgments (Little et al., 2013).

In sum, a number of explanations have been proposed to explain abnormal social approach behaviour in WS: increased social salience; attentional disengagement difficulties; amygdala dysfunction and frontal lobe dysfunction. A positive interpretation bias when identifying emotional expressions may also contribute to WS social behaviour. It is important to note that these explanations for WS social approach behaviour are not mutually exclusive and a single account is unlikely to fully explain social dysfunction in WS.

Autism Spectrum Disorder (ASD)

ASD is characterised by deficits in social interaction and social communication, as well as repetitive, stereotyped patterns of behaviour (American Psychiatric Association, 2013). While prevalence rates are difficult to ascertain due to recent changes in diagnostic criteria and improved awareness which has contributed to earlier diagnosis (see Leonard et al., 2010 for a discussion), recent census findings suggest that approximately 2% of Australians are diagnosed with an ASD (ABS, 2015). Despite the heterogeneity in symptoms and cognitive functioning, impairments in social functioning are a core feature of ASD with a reduced motivation to engage in social interactions thought to contribute to these impairments (Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012). Unlike individuals with WS, those with ASD: display attenuated approach behaviours compared to neurotypical individuals (Kim et al., 2015); show a reduced interest in people and social situations (Grelotti, Gauthier, & Schultz, 2002) and tend to avoid looking at the eyes (Tanaka & Sung, 2016). Moreover, individuals with ASD display impairments in both face processing (Weigelt, Koldewyn, & Kanwisher, 2012) and emotion recognition abilities (Uljarevic & Hamilton, 2013). This pattern of impairments led to the suggestion that ASD may be characterised by a core deficit in Theory of Mind (Baron-Cohen, 1995; Baron-Cohen, Lombardo, & Tager-Flusberg, 2013).

While faces seem to be particularly salient for WS individuals, the opposite pattern

is observed in ASD, that is, a reduced interest in faces is observed from a very young age (Zwaigenbaum et al., 2005). This reduced interest in faces led to the development of the social motivation theory of ASD (Chevallier et al., 2012). The social motivation theory of ASD proposes a diminished motivation to engage in social interactions and decreased attention to social stimuli such as faces in ASD, which contributes to the social impairments observed in ASD individuals. Empirical evidence for this account of social dysfunction in ASD comes from eye-tracking studies. Compared to neurotypical controls, ASD individuals spend less time looking at emotional (e.g. happy, angry, fearful) faces (see Black et al., 2017 for a review) , and spend less time looking at salient facial features, such as the eyes (see Chita-Tegmark, 2016 for a recent meta-analysis). However, studies employing the dot-probe paradigm have not found evidence that faces (threatening or positive) capture the attention of ASD individuals, nor do ASD individuals display difficulties disengaging their attention from faces (Hollocks, Ozsivadjian, Matthews, Howlin, & Simonoff, 2013; May, Cornish, & Rinehart, 2015). It is possible that these mixed findings may be attributable to the methodology used to measure attention for faces (eye-tracking versus dot-probe paradigms), heterogeneity across, and indeed, within studies, or a combination thereof. In an effort to explain the links between the atypical attention for faces often reported in eye-tracking studies and social dysfunction in ASD, an alternative account has recently been offered, namely, the eye avoidance hypothesis (Tanaka & Sung, 2016).

The eye avoidance hypothesis proposes that eye contact is perceived as threatening by ASD individuals and is thus avoided in an attempt to ameliorate discomfort (e.g. see Joseph, Ehrman, McNally, & Keehn, 2008; Kliemann, Dziobek, Hatri, Steimke, & Keekeren, 2010). Findings from both qualitative and eye-tracking studies appear to corroborate this account. Individuals with ASD state that they experience eye contact as distressing and overwhelming (Trevisan, Roberts, Lin, & Birmingham, 2017) and will

divert their gaze when prompted to look at the eye region of faces (Kliemann, Dziobek, Hatri, Baudewig, & Heekeren, 2012). Given that eye contact is an important component of social interactions (Itier & Batty, 2009), it is possible that this increased distress and avoidance may diminish one's ability to attain accurate information about facial expressions and social cues, thus contributing to the difficulties faced by ASD individuals in everyday social situations. However, it should be noted that conflicting findings are commonplace in the ASD literature and there appears to be considerable heterogeneity with respect to how social information is processed by individuals with ASD (e.g., see Pelphrey, Shultz, Hudac & Vander Wyk (2011); Plesa Skwerer (2017) for reviews). One domain, in particular, where inconsistent findings are widespread is that of emotion recognition.

While an increased interest in faces does not confer intact emotion recognition abilities in WS, it appears as though a decreased interest in faces may contribute to subtle difficulties in emotion recognition ability in ASD. While findings are mixed (see Harms, Martin and Wallace (2010) for a review) , it appears as though ASD individuals do display emotion recognition impairments when compared to neurotypical controls, with the largest impairments observed for negative emotional expressions (e.g. anger, fear) (see Uljarevic and Hamilton, (2013) for a meta-analysis. Moreover, there is preliminary evidence of a negative interpretation bias when identifying emotional expressions in ASD. Eack, Mazefsky, and Minshew (2015) found that those with ASD more frequently misclassified neutral faces as angry when compared to controls. This may partially explain the social withdrawal reported in ASD. That is, if neutral faces are perceived as threatening, this may point to a negative interpretation bias that could extend to social situations and interactions.

While much of the ASD literature to date has compared ASD individuals solely to neurotypical controls matched on chronological age or developmental level, a growing number of studies have compared social processing in WS and ASD, given the starkly

contrasting social phenotypes seen in these conditions. Of direct relevance to this thesis, Riby and Hancock conducted a series of eye-tracking studies where scanpaths to faces and social scenes were indirectly compared between WS and ASD individuals; indirectly compared because WS and ASD groups were matched to their own control groups, but were not directly compared to one another. In aggregate, this series of earlier studies indicated that WS individuals spent more time looking at faces relative to neurotypical controls, while ASD individuals spent less time looking at faces when compared to controls (Riby & Hancock, 2008, 2009a). Moreover, these findings appeared to generalise from static images to dynamic stimuli in both WS and ASD individuals (Riby & Hancock, 2009b), suggesting that face perception in day-to-day social situations may be characterised by these opposing scanpath patterns in WS and ASD individuals.

As is the case in the WS literature, a large amount of research in ASD has considered the role of amygdala and frontal lobe abnormalities in the observed social impairments (e.g. see Dichter, 2012; Philip et al., 2012 for reviews). Both structural (Schumann, Bauman, & Amaral, 2011) and functional abnormalities of the amygdala have been demonstrated in ASD, with reports of both increased (Weng et al., 2011) and decreased (Hadjikhani, Joseph, Snyder, & Tager-Flusberg, 2007) amygdala reactivity in response to faces. Of note, recent research suggests that the reduced eye contact seen in ASD may be related to amygdala dysfunction, with elevated amygdala reactivity observed when ASD individuals are required to look directly at the eyes of faces (Hadjikhani et al., 2017; Tottenham et al., 2014).

Moreover, in a similar vein to individuals with WS, ASD individuals display frontal lobe dysfunction. A meta-analysis from Philip et al. (2012) suggests that, compared to neurotypical controls, ASD individuals display hypoactivation in prefrontal brain regions when completing executive functioning tasks. Furthermore, as is the case with WS, executive functioning impairments have been reported in ASD (Hill, 2004) and have been

linked to social impairments (Leung, Vogan, Powell, Anagnostou, & Taylor, 2016) and increased levels of loneliness (Lieb & Bohnert, 2017) in ASD individuals.

Both amygdala and frontal lobe abnormalities have been put forth as likely explanations of social dysfunction in ASD. It is plausible that these neurological abnormalities lead to subsequent anomalies in behaviour. On the flip side, anomalous exposure, for example, in the form of increased or decreased exposure to faces or normal social interactions may disrupt normal brain development, known as experience-dependent synaptic plasticity (May, 2011; Zoghbi, 2003). Indeed, another thing to consider is that, as brain regions do not exist in isolation, both biological and environmental contributions to abnormal brain development are likely to affect the entire social network of the brain (Barak & Feng, 2016; Kennedy & Adolphs, 2012).

To summarise, some of the key accounts that have been put forward to explain abnormal social processing and behaviour in ASD include: social motivation theory; the eye avoidance hypothesis; amygdala dysfunction and frontal lobe dysfunction. As mentioned above, there is also preliminary evidence for a negative interpretation bias in this group. As is the case in WS, these explanations are not mutually exclusive, and a single account is unlikely to explain the full extent of social dysfunction in ASD.

Social Anxiety Disorder (SoAD)

SoAD is an anxiety disorder characterised by social avoidance and a fear of negative evaluation, affecting approximately 8.4% of Australians at some point in their lives (Crome et al., 2015). SoAD is believed to arise from genetic, temperamental and biological factors and tends to follow a chronic course (Hofmann, Boettcher, & Wu, 2015). Unlike WS and ASD, hypervigilance for social threat is believed to be central to the maintenance of SoAD, and likely contributes to the impairments in social interactions and fear of negative evaluation that compromise social functioning in this disorder (Wong & Rapee, 2016). Relative to neurotypical controls, individuals with SoAD: display decreased

social approach tendencies (Heuer, Rinck, & Becker, 2007); are more likely to misinterpret neutral expressions as threatening despite intact emotion recognition abilities (Bell et al., 2011; Peschard & Philippot, 2017); show hypervigilance for the eyes of emotional faces (Boll, Bartholomaeus, Peter, Lupke, & Gamer, 2016) and avoid maintaining eye contact for extended periods, particularly when looking at threatening emotional expressions (Chen & Clarke, 2017).

In contrast to individuals with WS or ASD, for SoAD individuals, threatening faces appear to be particularly salient. Theoretically, it has been proposed that increased attention towards social threat in one's environment is integral to the aetiology and maintenance of SoAD (Wong & Rapee, 2016). Some experimental findings support this proposal, with a recent meta-analysis of studies employing the dot-probe paradigm indicating that preferential allocation of attention towards threatening (angry and fearful) faces is observed in SoAD individuals, relative to neurotypical controls (Bantin, Stevens, Gerlach, & Hermann, 2016). Other experimental paradigms have led to less conclusive findings. For instance, a recent review of the eye-tracking literature in SoAD suggests that a combination of hypervigilant and avoidant attention patterns when presented with threatening (angry and fearful) faces may underpin SoAD (Chen & Clarke, 2017). Irrespective of the mechanism, hypervigilance or avoidance, it appears as though threatening faces are highly salient for those with SoAD and likely play into the social difficulties experienced by this group. Relatedly, theoretical and empirical research investigating the disengagement of attention from threat in SoAD suggests that a breakdown in this component of attentional processing may contribute to the difficulties experienced by SoAD individuals.

In contrast to the increased attention for positive faces seen in WS, and the decreased attention for faces in general reported in ASD, theoretical models of social anxiety propose that individuals with SoAD selectively allocate their attention to

threatening social stimuli and experience difficulties disengaging their attention from these stimuli, a pattern that likely perpetuates the social avoidance characteristic of SoAD (Rapee & Heimberg, 1997). Developed to explain impaired processing in anxiety disorders generally and since applied specifically to SoAD, attentional control theory posits that this initial vigilance for threat is driven by impairments in inhibition, while disengagement difficulties are believed to be underpinned by deficits in shifting attention away from threat (Eysenck, Derakshan, Santos, & Calvo, 2007). Empirical evidence from eye-tracking studies generally support this pattern of rapid attentional capture followed by delayed disengagement (Gamble & Rapee, 2010; Moriya & Tanno, 2011; Richards, Benson, Donnelly, & Hadwin, 2014), however, when faces are presented for longer periods, SoAD individuals tend to spend less time looking at threatening faces, and particularly the eye region of such faces, compared to neurotypical controls (Chen & Clarke, 2017). It is likely that methodological differences between studies (e.g., stimulus presentation time, whether selective attention to competing stimuli versus attentional maintenance to a single stimulus is observed) may influence findings (see Chen and Clarke, 2017 for a discussion).

In contrast to individuals with WS or ASD, individuals with SoAD do not demonstrate impairments in emotion recognition abilities, performing similarly to neurotypical controls on tasks of emotion recognition (Heuer, Lange, Isaac, Rinck, & Becker, 2010; Peschard & Philippot, 2017). However, as has been recently noted in ASD individuals, individuals with SoAD tend to demonstrate negative interpretation biases when labelling emotional faces. Numerous findings suggest that SoAD individuals more frequently label neutral faces as angry in comparison to neurotypical controls (Bell et al., 2011; Gutiérrez-García & Calvo, 2017). These findings align with the aforementioned theoretical models of SoAD, where threatening social stimuli are prioritised and preferentially attended to in one's environment.

As is the case in the WS and ASD literature, a considerable amount of

neuroimaging research has been conducted in SoAD, with findings suggesting that dysfunction in the amygdala and frontal lobes may represent neurological substrates for the social avoidance common of SoAD (for recent meta-analyses see Bruhl, Delsignore, Komossa, & Weidt, 2014 and Gentili et al., 2016). Relative to neurotypical controls, individuals with SoAD consistently display increased reactivity in the amygdala and prefrontal cortex in response to threatening faces (Bruhl et al., 2014). Moreover, a recent meta-analysis comparing WS and SoAD neuroimaging studies suggests that the amygdala may represent a common neural substrate for the atypical face processing common in WS and SoAD, with opposite patterns of activation – increased reactivity for positive (happy) faces in WS and increased reactivity for threatening (angry) faces in SoAD (Binelli et al., 2014). Finally, in line with the frontal lobe dysfunction reported in SoAD, there is some evidence that individuals with SoAD experience difficulties in certain components of executive functioning, with cognitive flexibility impairments related to increased symptom severity in SoAD individuals (Fujii et al., 2013).

In sum, key accounts that have been proposed to explain abnormal social behaviour in SoAD include: increased attention towards social threat; attentional control theory; amygdala dysfunction and frontal lobe dysfunction. As discussed above there is also evidence of a negative interpretation bias in SoAD individuals. As is the case in both WS and ASD, these accounts are by no means mutually exclusive and a single account is unlikely to fully explain the social abnormalities in SoAD.

The Importance of Cross-Disorder Comparisons

In some respects, WS, ASD and SoAD are three disorders that appear to represent different points on a continuum, at least where social processing and social behaviour are concerned. While hypersociability and elevated approach tendencies are considered hallmarks of WS, difficulties interacting with others and social withdrawal are common in ASD and SoAD. Further, while an increased interest in other people may underlie the

indiscriminate approach behaviour seen in WS, diminished social motivation is believed to contribute to the social interaction difficulties seen in ASD and an acute fear of negative evaluation by others is thought to underpin the social avoidance common in SoAD. To date, whilst similar experimental paradigms have been used to elucidate social processing abnormalities across these conditions (e.g. visual dot-probe, eye-tracking), the explanations that have been proposed to explain these social processing abnormalities are largely disorder-specific. Whilst such findings have provided invaluable information about social behaviour and function as it applies to a specific disorder, an unavoidable consequence of conducting research in silos is the lack of a single unifying theory that provides a framework for social function, and, perhaps more importantly, social *dysfunction,* across numerous conditions.

Indeed, following a review of the literature, it is apparent that individuals with WS, ASD or SoAD show similar social processing abnormalities, albeit in opposite directions. These social processing abnormalities may perhaps be considered as extreme dimensions on a continuum from avoidance to approach, diminished social motivation to increased social motivation, and decreased face salience to increased face salience. Yet, despite these extreme differences in social processing, individuals with WS, ASD or SoAD display similar functional deficits, broadly speaking, with social isolation, poor mental health outcomes and diminished interpersonal relationships reported in each group (Aderka et al., 2012; Jawaid et al., 2012).

It is rare to find studies that compare neurodevelopmental and anxiety disorders. Whilst some authors have cautioned, with good reason, against comparisons between neurodevelopmental disorders and acquired disorders (Karmiloff-Smith, 1997; Tager-Flusberg, Plesa Skwerer, & Joseph, 2006), it is worth noting that such comparisons have critically informed our understanding of social behaviour in both WS and ASD. For instance, early reports of apparent similarities between WS individuals and patients with

amygdala damage (Bellugi et al., 1999) have informed much of the extant social approach literature in WS (e.g. see Jarvinen-Pasley et al., 2010; Porter et al., 2007). Likewise, early predictions about the role of the amygdala in social behaviour in ASD individuals were informed by comparisons to patients with acquired amygdala damage (Adolphs, Sears, & Piven, 2001). Thus, while SoAD is a mental health condition which arguably has a very different developmental trajectory to neurodevelopmental disorders such as WS and ASD (although some have argued that SoAD should be conceptualised as a neurodevelopmental disorder, see Fox and Kalin (2014) and Mathew, Coplan and Gorman (2001) for discussion), it should not be omitted as a comparison group when investigating social behaviour on this basis alone. Indeed, given the opposing social behaviours seen in WS and SoAD (hypersociability in WS, avoidance in SoAD) and the more similar, yet by no means identical, social behaviours observed in ASD and SoAD (decreased social motivation and interest in ASD, social avoidance and fear of negative evaluation in SoAD), an investigation of social processing using a cross-disorder comparison with WS, ASD and SoAD is likely to elucidate qualitative similarities and differences between the conditions.

In a promising step forward, the importance of cross-disorder comparisons has been noted (e.g., see Brock, Einav, & Riby, 2008; Lough, Flynn, & Riby, 2014; Plesa Skwerer, 2017; Tyson & Cruess, 2012) , and research directly comparing distinct disorders is becoming more frequent (Bejerot, Eriksson, & Mortberg, 2014; Binelli et al., 2016; Lough et al., 2015; Rodgers, Riby, Janes, Connolly, & McConachie, 2012). These findings reveal an interesting pattern of similarities and differences across conditions. Despite their contrasting social profiles, both WS and ASD individuals seem to lack an awareness of personal space during social interactions (Lough et al., 2015). Further, when looking at faces, WS individuals display increased activation in brain regions involved in eye-gaze processing compared to SoAD individuals, consistent both with the increased salience of

faces reported in WS and the avoidance of eye contact seen in SoAD (Binelli et al., 2016). Finally, despite the apparent similarities between ASD and SoAD, there appear to be qualitative differences between these conditions; while ASD individuals display substantial difficulties in social reciprocity, those with SoAD tend to experience physiological symptoms (blushing, sweating) during social interactions (Bejerot et al., 2014). Such findings suggest that comparing and contrasting social behaviour in conditions featuring distinct social profiles may enhance our understanding of social dysfunction across numerous conditions.

The majority of the existing literature exploring face processing and its role in social behaviour across WS, ASD or SoAD has employed paradigms featuring emotional face stimuli (e.g. see Bantin et al., 2016; Black et al,, 2017; Goldman et al., 2016) , or pre-rated face stimuli varying on dimensions of perceived trustworthiness (e.g. see Adolphs et al., 2001; Bellugi et al., 1999). Whilst providing us with a wealth of knowledge about emotion perception and social processing abnormalities in these disorders, wide-ranging atypicalities in social behaviour have been reported in each disorder that seem to extend beyond the emotional expression or perceived trustworthiness of another person. For instance, in both WS and ASD, there is anecdotal evidence that individuals will interact with familiar people, even if they have previously had a negative experience those people, such as bullies at work or school, perhaps reflecting a lack of awareness that others can have negative or questionable intentions, or a decreased emphasis placed on this information, which may confer a vulnerability to exploitation (Jawaid et al., 2012; Lough et al., 2014). On the other hand, individuals with SoAD tend to interpret ambiguous social scenarios as excessively negative (Haller, Raeder, Scerif, Cohen Kadosh, & Lau, 2016), potentially reflecting the avoidance behaviour that occurs due to a fear of negative evaluation by others, even if the others in question are not known to be threatening. Given such reports, a consideration of social processing in these disorders using paradigms that

manipulate character-based, or biographical, information, as opposed to the more common manipulation of emotional expression, is warranted.

Using Faces to Inform Social Interactions – Social Perception and Biographical Information

Human faces, specifically identity and emotional expressions, convey perceptual information that is uniquely important in facilitating and guiding day-to-day social interactions. A happy face can trigger approach tendencies, while an angry face can capture our attention and alert us to potential threat (Adolphs, 2002). This type of perceptual information processing is important for successful navigation of the social world, however, not all relevant information we use to inform social interactions is directly observable. We also employ cognitive processing during social interactions, using our affective biographical knowledge of a person's character or attitudes to inform our social decisions and interactions. Although this significant biographical information cannot be perceived directly from the face, it plays a critical role in our evaluations of other people. Indeed, one may argue that this biographical knowledge of a person is often a more reliable indicator of their character than appearance (Shore & Heerey, 2013). For instance, a person displaying a happy or angry facial expression may also be known as a friendly childhood neighbour or, alternatively, as a schoolyard bully, pieces of salient biographical information that could assist in our social responses. Yet, while a substantial amount of research both in neurotypical individuals and neurodevelopmental and anxiety disorders has considered the influence of social-perceptual information on social decisions and interactions, the impact of biographical knowledge has only recently started to receive attention.

To date, research considering the role of biographical knowledge on subsequent social decisions, whilst focused primarily on neurotypical individuals, has revealed compelling results. The ability to learn salient biographical information about another

person appears to occur rapidly following minimal exposure and is retained over time (Bliss-Moreau, Barrett, & Wright, 2008). Further, associating neutral faces with positive or negative biographical information modulates subsequent evaluations and likeability ratings of the same faces (Abdel Rahman, 2011; Verosky, Porter, Martinez, & Todorov, 2018) as well as eliciting differential neural reactivity in brain regions generally associated with emotion and social processing, such as the amygdala (Baron, Gobbini, Engell, & Todorov, 2011; Charmet-Mougey, Rich, & Williams, 2012). Taken together, these findings suggest that biographical knowledge is used to inform social functioning and should be considered in disorders of social functioning.

Thesis Aims

Research to date has not explored social processing via a direct comparison of WS, ASD and SoAD, nor has research considered how biographical information may influence face processing in neurodevelopmental or anxiety disorders where atypicalities in face processing for emotional expressions have already been established. The overall aim of this thesis, therefore, was to utilise a cross-disorder comparison to explore the influence of biographical information on social processing in individuals with WS, ASD or SoAD. More specifically, across five papers this thesis explored group differences in attentional biases, emotion recognition abilities, the salience of certain face regions (such as the eyes) and approach/avoidance decisions when individuals were required to rely on biographical, as opposed to emotional, information.

Aims of Individual Papers

The five papers in this thesis explore social processing across WS, ASD and SoAD, utilising a cross-disorder comparison and novel experimental paradigm to extend the current literature and broaden our understanding of the distinctive social profiles seen in each disorder. The specific aims and research questions addressed by each paper are

outlined below.

Paper 1

Paper 1 attempted to broaden Dodd and Porter's (2010) finding of an attention bias for happy faces in WS individuals when compared to neurotypical controls using a dot-probe paradigm. Paper 1 employed biographical face stimuli, namely perceptually neutral faces that were paired with either positive (trustworthy), neutral, or negative (untrustworthy) biographical information, rather than faces displaying emotional expressions. The core aim of this paper was to determine whether WS individuals were able to associate neutral faces with salient biographical information, and whether the positive attention bias observed in WS extends to faces paired with trustworthy biographical information. It was hypothesised that WS individuals would display an attention bias to faces paired with trustworthy biographical information, relative to neurotypical controls. Given that the previously observed attentional biases for happy faces are thought to represent amygdala dysfunction in WS (Dodd & Porter, 2010), an attention bias for faces paired with trustworthy biographical information would provide preliminary, albeit indirect, evidence for the role of the amygdala in processing biographical information in WS. Moreover, it was hypothesised that this bias for trustworthy biographical faces would be driven by attentional disengagement, in line with the proposal made by Riby et al. (2011), where difficulties disengaging attention from faces are thought to contribute to the increased interest in faces seen in WS.

Further, following from the findings of McGrath et al. (2016), where attentional biases in WS individuals were mediated by anxiety and IQ, a sub-aim of Paper 1 was to investigate the relationship between attention biases, anxiety and cognitive ability in WS individuals.

Paper 2

Paper 2 built on Paper 1, with the aim of directly comparing attention biases in WS,

ASD, SoAD and neurotypical individuals, utilising a dot-probe task and biographical face stimuli. This paper also included the investigation of a novel attention bias index, attention bias variability, a dynamic measure of attention bias that reflects individual fluctuations in one's attention bias across the testing session, rather than a single summary bias score. It was hypothesised that the attention bias for faces paired with trustworthy biographical information seen in the WS group would be larger than that seen in both the ASD and SoAD groups. Conversely, it was predicted that no attention bias for faces paired with trustworthy or untrustworthy biographical information would be observed in the ASD group, in line with the social motivation theory of ASD (Chevallier et al., 2012). Finally, an attention bias for faces paired with untrustworthy biographical information was predicted in the SoAD group relative to WS individuals and neurotypical controls, in line with theoretical models of SoAD, where individuals are thought to prioritise social threat (Rapee & Heimberg, 1997; Wong & Rapee, 2016).

Paper 3

The principal aim of Paper 3 was to investigate whether learning prior biographical information about a face directly influenced the perception of emotional expressions, and, if so, whether these differences varied between WS, ASD and SoAD individuals (as well as neurotypical controls). Both accuracy rates and misclassification tendencies were investigated, and it was hypothesised that WS individuals would display a specific deficit in identifying angry and neutral expressions relative to ASD, SoAD and neurotypical control groups, while ASD individuals were anticipated to display a deficit in recognition of angry and neutral expressions relative to neurotypical controls. Moreover, it was predicted that WS individuals would be more likely to classify neutral expressions as happy, while it was anticipated ASD and SoAD individuals would be more likely to classify neutral expressions as angry. More frequent misclassifications of neutral faces as happy would provide evidence for a positive interpretation bias in WS, while more

frequent misclassifications of neutral faces as angry would support proposals of negative interpretations biases in ASD (Eack et al., 2015) and SoAD (Peschard & Philippot, 2017). Additionally, it was predicted that both accuracy rates and the type of misclassifications made would be influenced by the biographical information paired with a given face, thus further informing our understanding of the influence of biographical information on face perception.

Paper 4

The primary aim of Paper 4 was to investigate visual attention to faces that had been paired with biographical information across WS, ASD, SoAD and neurotypical individuals using eye tracking, and more particularly, to explore attentional capture and attentional disengagement from the eye region of biographical faces. Further, the relationship between executive functioning impairments and initial patterns of visual attention was explored. Whilst no specific hypotheses were made, associations between executive functioning impairments and visual attention would indirectly inform an understanding of frontal lobe dysfunction in WS, ASD and SoAD.

It was hypothesised that WS individuals would spend more time looking at salient face features in comparison to ASD, SoAD and neurotypical individuals, consistent with predictions of the social salience hypothesis (Frigerio et al., 2006). Moreover, in line with both the social motivation theory of ASD (Chevallier et al., 2012) and the eye avoidance hypothesis (Tanaka & Sung, 2016), it was hypothesised that ASD individuals would spend less time looking at salient face features relative to neurotypical individuals, whilst it was predicted that SoAD individuals would spent less time looking at salient face features specifically for untrustworthy biographical faces compared to neurotypical controls, consistent with the avoidance of threatening faces observed in SoAD when faces are displayed for longer periods (Chen & Clarke, 2017).

With respect to attentional capture and attentional disengagement from the eye

region of biographical faces, it was hypothesised that WS individuals would experience difficulties disengaging their attention from the eye region of all faces compared to ASD and neurotypical individuals, in line with the proposal that increased face salience is driven by disengagement difficulties in WS (Riby et al., 2011). Further, relative to WS, SoAD and neurotypical individuals, ASD individuals were not anticipated to show any effects of attentional capture for the eye region, in line with the social motivation theory of ASD (Chevallier et al., 2012), however it was predicted that ASD individuals would disengage their attention from the eye region more rapidly, which would provide support for the eye avoidance hypothesis (Tanaka & Sung, 2016). Finally, it was hypothesised that SoAD individuals would display faster attention capture to the eye region of all faces compared to WS, ASD and neurotypical individuals and would show difficulties disengaging attention from the eye region compared to ASD and neurotypical individuals, consistent with predictions made by attentional control theory (Eysenck et al., 2007).

Paper 5

Using the same biographical paradigm employed in Papers 1 to 4, the aims of Paper 5 were twofold. First, social approach judgements for trustworthy, neutral and untrustworthy biographical faces were directly compared between WS, ASD, SoAD and neurotypical individuals. Secondly, group differences in the time spent looking at the eye region of biographical faces were explored. An additional aim and novel aspect of this paper was to explore eye gaze patterns to the social approach scale to better understand how approach judgments are made in individuals with WS, ASD or SoAD, as well as in neurotypical controls.

It was hypothesised that WS individuals would judge trustworthy biographical faces as more approachable than ASD, SoAD and neurotypical individuals. Indirectly, such a finding may inform our understanding of amygdala dysfunction across WS, ASD and SoAD. That is, amygdala dysfunction is believed to represent a neural substrate of social

behaviour in WS, ASD and SoAD and the amygdala itself has been critically linked to approach judgments (Adolphs et al., 1998), thus, atypical approach judgments for biographical faces in WS, ASD or SoAD individuals would indirectly elucidate the role of the amygdala in biographical information processing. Moreover, it was anticipated that WS individuals would look at the eye regions of all faces for longer periods compared to ASD individuals, consistent with predictions made by both the social salience hypothesis of WS (Frigerio et al., 2006) and the eye avoidance hypothesis in ASD (Tanaka & Sung, 2016). Further, it was hypothesised that SoAD individuals would spend less time overall looking at the eye regions of untrustworthy biographical faces compared to both WS individuals and neurotypical controls, in line with the avoidance of eye contact seen in SoAD for threatening faces (Chen & Clarke, 2017; Wong & Rapee, 2016).

Summary

In summary, many different explanations have been proposed to account for the social processing anomalies seen in WS, ASD or SoAD, with evidence of some overlap and some differences across conditions, both in terms of social processing anomalies and explanations thereof. Taken together, common areas of research across the three conditions include attentional biases towards positive or threatening faces, emotion recognition, the salience of face regions (particularly the eyes) and approach/avoidance tendencies. Whilst similar experimental paradigms have been used across conditions, such as dot-probe and eye-tracking paradigms, research has yet to directly compare and contrast social processing abilities in these conditions. Moreover, previous research in each condition has used emotional face stimuli to gauge social processing deficiencies, rather than biographical stimuli. As such, the central aim of this thesis was to assess the influence of biographical information on social processing in individuals with WS, ASD or SoAD, adopting a cross-disorder comparison.

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Paper 1

Extending the Positive Bias in Williams syndrome: The Influence of Biographical Information on Attention Allocation

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Abstract

Introduction: There is evidence that individuals with Williams syndrome (WS) show an attention bias towards positive social-perceptual (happy) faces. Research has not yet considered whether this attention bias extends beyond social-perceptual stimuli to perceptually neutral stimuli that are paired with positive (trustworthy) biographical information.

Method: Fourteen participants with WS (mean age = 21 years, 1 month) learnt to associate perceptually neutral faces with trustworthy (positive), neutral, or untrustworthy (negative) biographical information, before completing a dot-probe task where the same biographical faces were presented. The performance of the WS group was compared to two typically developing control groups, individually matched to the WS individuals on chronological age or mental age, respectively.

Results: No between-group bias towards untrustworthy characters was observed. The WS group displayed a selective attention bias towards trustworthy characters compared to both control groups (who did not show such a bias).

Conclusion: Results support previous findings that indicate WS individuals show a preference for positive social-perceptual stimuli (happy faces) at the neurological, physiological and attentional levels. The current findings extend this work to include a 'top-down' positive bias. The implications of a positive bias that extends beyond social-perceptual stimuli (or 'bottom-up' processes) in this syndrome are discussed.

Extending the Positive Bias in Williams syndrome: The Influence of Biographical Information on Attention Allocation

Introduction

Williams syndrome (WS) is a neurodevelopmental disorder caused by the deletion of approximately 26 to 28 genes on the long arm of chromosome 7 at 7q11.23 (Ewart, 1993). The estimated prevalence rates of WS is approximately 1 per 7,500 (Strømme et al., 2002). Alongside an intellectual impairment, typically in the mild to moderate range (Martens, Wilson, & Reutens, 2008), one of the cardinal features of WS is a unique social phenotype, with affected individuals displaying hypersocial behaviour and a drive for social engagement and interaction, both with familiar others and with strangers (Bellugi et al., 1999; Doyle et al., 2004; Jones et al., 2000; Thurman & Fisher, 2015). In addition to this hypersociability, empirically, individuals with WS generally display a striking bias towards positive social stimuli, particularly happy facial expressions, which has been demonstrated across neurological (Haas et al., 2009; Haas & Reiss, 2012), physiological (Jarvinen, Ng, Crivelli, Arnold, et al., 2015; Plesa Skwerer et al., 2009) and attentional (Dodd & Porter, 2010; Goldman et al., 2016) measures. This strong positive bias is thought to at least partially underlie the heightened and indiscriminate social approach (Jarvinen et al., 2013) and social trust (Riby, Kirk, Hanley, & Riby, 2014) reported in this population.

A neurological basis to the positive social bias

Abnormal structure (Reiss et al., 2004) and function (Meyer-Lindenberg et al., 2005) of the amygdala, alongside dysfunction in fronto-striatal regions (Mimura et al., 2010) have been implicated in the atypical positive social bias observed in WS. Meyer-Lindenberg et al. (2005) found that WS individuals displayed decreased amygdala reactivity in response to threatening (angry and fearful) faces, relative to neurotypical controls. Likewise, compared to chronological-age matched controls, a lack of activation in the orbitofrontal cortex was observed in WS participants in response to threatening faces.

The authors proposed that these atypical brain responses reflected a neurological basis for the hypersociablity and a lack of awareness of social cues often seen in this population. However, only WS individuals whose IQ scores were within the normal range were included in this study, limiting the generalizability of these findings. Moreover, the authors did not explore amygdala or frontal reactivity to happy faces (Meyer-Lindenberg et al., 2005).

Using event-related potentials and functional magnetic resonance imaging, Haas et al. (2009) demonstrated abnormal amygdala reactivity to both threatening (fearful) and positive (happy) emotional facial expressions in a cohort of WS individuals with an overall level of intellectual impairment within the mild range. Compared to both neurotypical individuals matched on chronological age and individuals with non-specific developmental disabilities, WS individuals displayed increased amygdala reactivity to happy faces, alongside attenuated amygdala activity to fearful faces. In line with Meyer-Lindenberg et al. (2005), the authors suggested that atypical amygdala function may contribute to the WS social phenotype, by increasing arousal to positive expressions and decreasing arousal to threatening expressions.

Mimura et al. (2010) looked at amygdala reactivity to happy and angry faces. Consistent with both Meyer-Lindenberg et al. (2005) and Haas et al. (2009), Mimura et al. (2010) found decreased amygdala reactivity to angry faces in WS individuals relative to a group of neurotypical individuals matched on chronological age. Extending the initial findings of Meyer-Lindenberg et al. (2005), where WS individuals displayed decreased orbitofrontal cortex reactivity to angry and fearful faces relative to controls, Mimura and colleagues reported a unique pattern of reactivity to happy and angry faces in WS individuals when looking at the lateral and medial portions of the orbitofrontal cortex separately. Relative to chronological age-matched controls, WS individuals displayed decreased reactivity to angry faces in the lateral portion of the orbitofrontal cortex. The

opposite pattern was observed in the medial portion of the orbitofrontal cortex, with increased reactivity in response to angry faces seen in WS individuals compared to controls. Further, reactivity to happy faces was similar in both the lateral and medial portions of the orbitofrontal cortex in WS individuals, whereas controls displayed increased reactivity to happy faces in the medial portion of the orbitofrontal cortex compared to the lateral portion, suggesting that happy faces differentially activated the lateral and medial portions of the orbitofrontal cortex in neurotypical individuals, but not in WS individuals. The authors noted that activity in the lateral orbitofrontal cortex is related to the evaluation of punishment value, while activity in the medial orbitofrontal cortex is related to the learning and memory of reward. Given these separable roles, Mimura et al. (2010) proposed that angry faces were processed as both less punishing and more rewarding by WS individuals relative to controls. Likewise, while the increased reactivity to happy faces in the medial orbitofrontal cortex indicated that happy faces were processed as more rewarding in the control group, the WS group showed similar reactivity to happy faces in both the lateral and medial portions of the orbitofrontal cortex, suggesting abnormalities when processing happy faces.

A physiological basis for the positive social bias

A growing body of research has utilised various physiological indices, such as heart rate, skin conductance and pupil size during social processing tasks in WS (see Jarvinen and Bellugi (2013) for a review). Results in this field are largely convergent, with hypoarousal to negative stimuli reported across the majority of studies regardless of measurement indices. Relative to age-matched neurotypical individuals and IQ-matched individuals with non-specific developmental disabilities, WS individuals display reduced skin conductance amplitudes and increased heart rate deceleration in response to angry faces (Plesa Skwerer et al., 2009). Similarly, when presented with images portraying negative social scenarios, WS individuals show smaller differences in pupil dilation,

compared to neurotypical controls matched on chronological age (Plesa Skwerer et al., 2011). Plesa-Skwerer and colleagues interpret these findings as evidence of decreased threat-detection for negative social images. Physiological studies align with the aforementioned findings of attenuated amygdala reactivity to angry and fearful faces.

Using skin conductance response measures, Jarvinen et al. (2015) found that WS individuals exhibited a lack of habituation for happy faces, relative to controls matched on chronological age. This finding was paired with decreased arousal for fearful faces in the WS group, relative to controls. The authors interpreted the lack of habituation for happy faces as a physiological manifestation of amygdala dysfunction, in particular, hypervigilance of the amygdala for happy faces. Taken together, these physiological findings mirror those observed at the neurological level, where amygdala activity is atypical and mediated by face valence (Haas et al., 2009; Meyer-Lindenberg et al., 2005), and suggest that atypical amygdala reactivity to angry and happy faces may have cascading effects on physiological arousal in WS individuals.

An attentional basis for the positive social bias

In other attempts to explain the hypersociability seen in WS, this time at an attentional level, research has explored whether social stimuli, particularly faces, capture the attention of WS individuals (Goldman et al., 2016), or whether WS individuals have difficulty disengaging attention from faces (Riby & Hancock, 2009a). Results in this area have been mixed, which may reflect differences in the methodologies used across studies, the clinical variability in WS (Brawn & Porter, 2017), or both.

Research exploring attention to faces in WS using eye-tracking suggests that WS individuals experience difficulty disengaging their attention from faces, spending more time looking at faces as a result (Porter et al., 2010; Riby & Hancock, 2009a). Of note and in contrast to findings in the neurological and physiological literature, these disengagement difficulties do not appear to be mediated by the emotional valence of the face, with WS

individuals spending more time looking at both happy and angry facial expressions relative to neurotypical controls matched on mental age (Porter et al., 2010). Despite the heightened social drive and extreme interest in faces seen in WS, faces do not seem to preferentially capture the attention of these individuals, that is, the time taken to make an initial fixation on a face does not differ between WS individuals and mental age-matched controls (Porter et al., 2010; Riby & Hancock, 2009a). Riby et al. (2011) suggested that the social salience of faces is overpowering for WS individuals, and it is this salience that holds their attention, with individuals taking more time to disengage from faces compared to objects, relative to neurotypical controls matched on chronological or mental age (Riby & Hancock, 2009a; Riby et al., 2011).

Research comparing patterns of attention allocation for emotional facial expressions in WS have also utilised alternate modalities such as the dot-probe task. Despite the use of similar paradigms and stimuli, some dot-probe studies have reported evidence of disengagement difficulties in response to happy faces (Dodd & Porter, 2010; McGrath et al., 2016), whilst others have found evidence to suggest that happy faces capture the attention of WS individuals (Goldman et al., 2016). It is possible that these discrepant findings are the result of sampling differences, with demographics such as chronological age and IQ varying across studies, or they may possibly reflect the general clinical variability seen in WS (Rossi, Moretti-Ferreira, & Giacheti, 2006). Despite the discrepant findings, the majority of prior research looking at attention allocation using the dot-probe task suggests that the valence of the face is important, with WS individuals displaying a clear attention bias towards happy faces (whether via attention capture or disengagement), but not angry faces (Dodd & Porter, 2010; Goldman et al., 2016). These findings align with neurological and physiological findings, and suggest that the bias for positive social stimuli characteristic of WS is also observed at the attentional level.

Building on existing research in the area of attention allocation, McGrath et al.

(2016) found that the positive bias in WS appeared to be mediated by anxiety and level of IQ. Utilising a dot-probe task in a large sample of WS individuals (n = 46), the authors found that a bias towards happy faces was only observed in WS individuals who displayed lower levels of overall anxiety on the Spence Children's Anxiety Scale parent-report form (Spence, 1998), and decreased verbal IQ, measured using the Kaufman Brief Intelligence Test–2nd Edition (Kaufman & Kaufman, 2004). In contrast, McGrath et al. (2016) found that a bias towards angry faces was significantly and positively correlated with both anxiety and verbal IQ. Verbal IQ was selected as the primary index of cognitive functioning, however the authors noted that results were comparable when nonverbal IQ was used. This study suggests that the positive social bias often reported in WS may be influenced to some degree by cognitive and psychological factors.

Whilst the dot-probe task has been used extensively within the WS literature and is commonly used to assess attentional bias to threat in other populations, such as anxiety disorders (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van, 2007), there is some debate regarding the reliability and interpretability of this measure when assessing attentional biases. Looking at a sample of neurotypical individuals with elevated anxiety, Waechter, Nelson, Wright, Hyatt, and Oakman (2013) found that attention bias indices from the dot-probe task showed low reliability. The authors suggested that these low reliability estimates may explain the contradictory findings within the anxiety literature when attention to threat is measured using dot-probe paradigms (see Bantin, Stevens, Gerlach and Hermann, 2016 for a meta-analysis of studies using the dot-probe paradigm in social anxiety). It is possible that some of the concerns around the reliability of the dot-probe task and the contradictory findings arising from this paradigm noted by Waechter et al. (2013) may occur as a result of sampling inconsistencies (Bantin et al., 2016). Moreover, whilst there has been some contention within the WS literature as to which component of attention the dot-probe task is measuring (attentional capture or attentional

disengagement), the net findings across studies and samples have been the same, whereby WS individuals tend to display an attention bias towards happy faces. Whilst the potential limitations of the dot-probe paradigm should not be disregarded, when used with WS individuals, this paradigm appears to be a useful measure of attention bias and has provided valuable evidence for an attentional component for the positive social bias seen in this population.

Research on social processing in WS to date has focused on responses to social-perceptual stimuli, utilising face stimuli displaying various emotional expressions. While social-perceptual stimuli such as facial emotional expressions are important in helping us navigate the social world, they are just one feature that we use when making decisions about whether to engage in or avoid social interactions (McCarthy & Skowronski, 2011). For example, there are often top-down biographical details and schemas that help inform us about who we want to look at, attend to and interact with socially. Whilst we cannot perceive this information directly from the face, the salient biographical information we know about a person (for instance, are they a friend or an adversary) can critically inform our evaluations and social decisions, for example, whether to approach or avoid (Cassidy & Gutchess, 2015). This information can even affect our neurological responses, with neutral faces paired with positive or negative biographical information found to elicit differential neural reactivity in brain regions generally associated with emotion and social processing, such as the amygdala (Abdel Rahman, 2011; Baron et al., 2011; Charmet-Mougey, Rich, & Williams, 2012).

Investigating the positive social bias in WS and going beyond social-perceptual information

The primary aim of the current study was to investigate the influence of top-down biographical information on attention bias in WS and in neurotypical controls matched on chronological or mental age, using a dot-probe task. Whilst prior research has explored

attention bias in WS when faces are manipulated perceptually (different emotional expressions) (Dodd & Porter, 2010; McGrath et al., 2016), the present study required participants to use top-down processing (learned biographical information) rather than bottom-up (perceptual) processing. We explored within- and between-group differences in attention biases to trustworthy characters – perceptually neutral face stimuli paired with trustworthy (positive) biographical information, and untrustworthy characters – perceptually neutral face stimuli paired with untrustworthy (negative) biographical information.

Based on the research outlined in the introduction, it was hypothesised that WS participants would display an attention bias towards trustworthy characters but not untrustworthy characters. No within-group attention bias was anticipated in either control group. Our second hypothesis was that the WS group would display a larger attention bias towards trustworthy characters compared to both control groups. In contrast, no between group differences were hypothesised for untrustworthy characters. In line with the disengagement account of social attention in WS (Riby et al., 2011) and the findings of Dodd and Porter (2010), we hypothesised that the attention bias towards trustworthy characters in WS would be driven by difficulties in disengaging attention, rather than attention capture. This was explored by including a neutral condition in which face stimuli paired with neutral biographical information were presented, to distinguish between capture and disengagement effects. To control for group differences in recognition ability, a recognition task for the faces that had been paired with biographical information was conducted following completion of the dot-probe task. No specific hypotheses were made with respect to recognition ability, given that a task of this nature has not previously been used in WS.

A secondary aim of the current study was to explore the relationship between attention bias and IQ or anxiety, respectively in the WS group. In line with McGrath et al.

(2016), we hypothesised that WS individuals with lower IQ would display a larger attention bias towards trustworthy characters relative to those with higher IQ. Similarly, we predicted a larger attention bias towards trustworthy characters in WS individuals with lower levels of anxiety, compared to those with higher levels of anxiety.

Method

Participants

The study involved 42 participants: 14 participants with WS and 28 neurotypical participants. These participants were recruited for a series of studies, as reported in Boulton, Porter, and Wong (2018a, 2018b, 2018c, 2018d). Demographic information for each group is shown in Table 1.

Williams syndrome group. Fourteen WS participants (7 male) were recruited through Williams Syndrome Australia Limited. All participants with WS had a positive fluorescent in situ hybridisation (FISH) test showing deletion of the elastin gene at 7q11.23 (Fryssira et al., 1997). Mental age and IQ were determined using the Woodcock-Johnson Tests of Cognitive Ability – 3rd Edition (WJ-III COG; Woodcock, McGrew & Mather, 2001). IQ scores ranged from 52 to 83, with an average of 66, representing a mild to moderate impairment on average, suggesting a representative sample in terms of IQ (Mervis et al., 2000).

Mental age comparison group. Fourteen neurotypical children (9 male) were recruited through the Macquarie University Neuronauts Brain Science Club, a register of children and adolescents who elect to take part in research projects at Macquarie University. Children were screened via a clinical interview and exclusion criteria included a history of developmental delay, intellectual impairment, learning difficulties, neurological illness or impairment, or a clinical diagnosis (such as a psychological condition) or sensory impairment). No participants met exclusionary criteria. In addition, all control participants were considered to be typically developing by their primary

caregivers. IQ and mental age for the mental age (MA) comparison group was established using the WJ-III COG (Woodcock et al., 2001). The MA group were closely matched to the WS group in mental age (see Table 1). Further, a paired-samples t-test was conducted to compare the difference in the chronological age and mental age (derived from WJ-III COG) of the MA group. No significant difference was observed, $t(13)=-.120$, $p=.906$.

Chronological age comparison group. Fourteen neurotypical participants (5 male) matched to the WS group on chronological age (CA) were recruited through the Macquarie University Neuronauts Brain Science Club or through the Macquarie University undergraduate psychology participation pool, a register of University students who participate in research in return for course credit. The same exclusion criteria were used as for the MA-matched controls. No participants met exclusionary criteria. All participants were neurotypical.

Table 1

Mean characteristics for all groups

	WS (*n*=14)	CA matched controls (*n*=14)	MA matched controls (*n*=14)	*t*	*p*
CA in years	21.03 (7.99)	21.02 (6.67)	8.82 (1.48)	.014	.989
Mean (SD) *range*	*13.50 – 44.58*	*11.42 – 37.50*	*6.42 – 11.08*		
MA in years	8.16 (1.71)	_	8.86 (3.83)	.648	.525
Mean (SD) *range*	*5.75 – 11.92*		*4.92 – 17.83*		

Note: WS=Williams syndrome; CA=Chronological age-matched controls; MA=mental age-matched controls.

Measures

The Spence Children's Anxiety Scale (SCAS; Spence 1998). The SCAS was administered to parents of WS individuals (Nauta et al., 2004; Spence, 1998). Previous studies have successfully used this scale with children, adolescents, and adults with WS (Dodd, Schniering, & Porter, 2009; McGrath et al., 2016). The SCAS contains 38 items in total, with six subscales, evaluating symptoms on differing domains of anxiety (Nauta et

al., 2004).

Woodcock-Johnson Tests of Cognitive Ability – 3rd Edition (WJ-III COG; Woodcock et al., 2001). The WJ-III COG (Woodcock, McGrew & Mather, 2001) provides an estimate of verbal IQ, non-verbal IQ, and full-scale IQ. Raw scores on the WJ-III COG can be converted into *W* scores (centred on a value of 500), the initial metric for all derived scores available for the WJ-III COG, as well as standard scores (with population *M*=100, *SD*=15). It has been noted that *W* scores are more sensitive to an individual's level of ability and performance on a given task relative to standard scores, due to their equal-interval scale (Jaffe, 2009). As such, *W* scores were used to investigate associations between IQ and attentional biases, however standard scores are also reported for ease of interpretation.

Biographical learning task. The current study adapted a biographical face learning paradigm developed by Charmet-Mougey et al. (2012). The initial paradigm was developed to explore the effect of semantic information on perceptual stimuli and required participants to memorise salient biographical vignettes paired with neutral faces. The vignettes described the faces as benevolent, neutral or malevolent characters. A key caveat to the original paradigm was its relative complexity, as the task required requisite skills in memory that are compromised in WS, and are not mature or fully developed in neurotypical children.

In line with the original paradigm, 24 faces were used to present biographical information, however, two key modifications were made to account for the compromised and underdeveloped memory skills in our populations of interest. Firstly, the modified paradigm presented three biographical vignettes, as opposed to the 24 vignettes in the original paradigm. Images from 24 different actors (12 male, 12 female) displaying neutral expressions were taken from the NimStim standardised face set (Tottenham et al., 2009). The 24 faces were divided into three blocks: (1) *trustworthy characters*, where the

characters were described as trustworthy or 'good'; (2) *neutral characters,* where the characters were described as neutral, or 'neither good nor bad'; and (3) *untrustworthy characters*, where the characters were described as untrustworthy or 'bad'. For the full content of these vignettes, see Appendix A.

There were four male and four female faces in each block, and the character types corresponding to each block were counterbalanced across participants to control for any biases in responding. The modified version of the biographical learning task presented each block of faces with a colour tint during the training phase to facilitate learning. When learning which character types the neutral faces belonged to, each block was tinted blue, purple or orange, using LunaPic online picture editing software (www.lunapic.com). These colours were selected as they were considered to be relatively neutral and unlikely to be implicitly associated with emotionally salient information. The colour tints corresponding to character types were counterbalanced across participants. Once participants were able to correctly label the character type of each face at an accuracy level of at least 80%, the dot-probe and character recognition tasks were conducted using the faces in greyscale. Based on our qualitative observations during the biographical face learning task, while the CA control group tended to learn which faces belonged to each character type more quickly than both the WS and MA control groups, the WS group experienced fewer difficulties when learning biographical faces compared to the MA control group.

Dot probe task. The dot-probe task used in the current study was adapted from prior tasks used with WS individuals (Dodd & Porter, 2010) and involved the simultaneous presentation of a biographically neutral stimulus and a biographically salient stimulus (trustworthy or untrustworthy), followed by the presentation of a probe in the same location as either the neutral or salient stimulus, which participants were instructed to respond to as quickly as possible. Both within-subject and between-subject attention biases were investigated. A within-subject bias is reported when responses to the probe are

significantly faster following a salient stimulus (congruent trial) as opposed to a neutral stimulus (incongruent trial). When significant differences in the size of the bias (congruent trials – incongruent trials) are found between multiple groups, a between-subject bias is reported. Whilst the utility and interpretability of the dot-probe task has been somewhat disputed (Waechter et al., 2013), this task has provided valuable insight into the link between mechanisms of attention and observable social behaviours in WS (Dodd & Porter, 2010; Goldman et al., 2016).

In line with Dodd and Porter (2010), the dot-probe task in the current study included a total of 288 experimental trials divided into 12 blocks, each comprised of 24 trials. There were 16 critical trials incorporated in each block: eight in which a trustworthy character was presented side by side with a neutral character and eight in which an untrustworthy character was presented side by side with a neutral character. In addition to the critical trials, each block also included eight neutral trials, with two neutral characters being presented side by side, to provide a baseline for participants' reaction time when the character manipulation was not presented. Further, the inclusion of a neutral condition allowed us to distinguish between attentional capture and disengage effects. A significant different between neutral trial and congruent trials would represent a capture effect, suggesting that the salient biographical stimulus is capturing the attention of the participant. In contrast, a significant difference between neutral and incongruent trials would represent a disengagement effect, suggesting that participants are experiencing difficulties disengaging their attention from the salient biographical stimulus to respond to the probe in another location. Character manipulation (trustworthy/untrustworthy), character position (left/right), and probe position (left/right) were ordered such that each block included four trustworthy-congruent trials, four trustworthy-incongruent trials, four untrustworthy-congruent trials, and four untrustworthy-incongruent trials. Trials were randomised within blocks for each participant. The position of the character manipulation

and probe were counterbalanced within conditions. The position of the probe throughout the eight neutral trials was also counterbalanced. The dot-probe task was programmed using DMDX (Forster & Forster, 2003) and presented on a Samsung 27" LED monitor.

Procedure

The study was approved by the Macquarie University Human Research Ethics Committee. Informed consent was obtained from the participants or their parents/caregivers, as appropriate. WS and MA-matched controls were provided with an explanation of the study that was commensurate with their level of understanding and were asked if they would like to participate. Participants were tested in a quiet room at Macquarie University. Participants sat approximately 60 cm away from the computer screen. The cognitive assessment and biographical learning task took approximately 90 minutes to complete. Following this, participants completed the dot-probe and character recognition tasks, which took approximately 25 minutes to complete. Breaks were provided throughout the session as necessary. A probe-detection task was chosen over a probe-classification task (where participants are required to classify the type of probe from two options rather than simply detecting the probe), to keep the attention task as simple as possible.

The procedure for the dot-probe task was based on that used in previous studies with WS individuals (Dodd & Porter, 2010). Each trial began with a black fixation cross in the centre of a white background for 500ms followed by presentation of the two images on the left and right side of the fixation cross for 500ms. The inner edge of each image was 1.6 cm away from the fixation cross and each image was 13.44 cm (506 pixels) wide by 16.35 cm (618 pixels) high with a visual angle of 12.78°. The two images were followed immediately by a probe presented in the centre of the space occupied by one of the two previous images. The probe was a black dot measuring 0.4 cm, and was presented 4.4 cm away from the fixation cross. The sequence of events on a trial is described in Figure 1.

Participants were provided with a parallel input/output interface with custom button box, which had a centre button, a button on the left, and a button on the right and were told to press the button that corresponded to the side the probe was on as quickly as possible. The probe remained on the screen until a response had been made, or until 10 seconds had passed. Participants' response to the probe, or the timeout of the probe was followed by a 100 tick (approximately 1672ms) intertrial interval. The experiment ran through blocks continuously. Participants were told that they could take a break at the end of each block and were instructed to press the centre button of the button box when they were ready to continue. The fixation cross remained on the screen throughout each block. Six practice trials were completed at the start of the experiment and participants were given an opportunity to ask any questions before the experimental trials began. Accuracy and reaction time (RT) data were recorded for all trials.

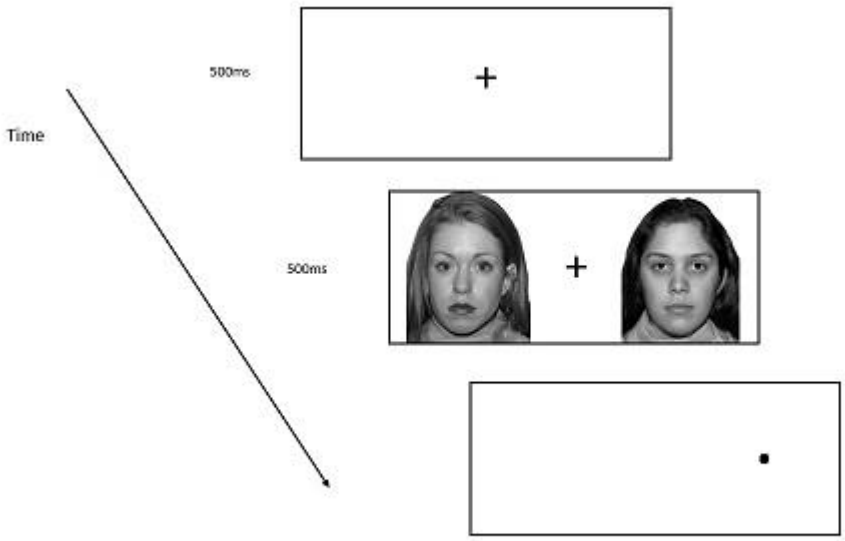

Figure 1. Sequence of events in dot-probe task.

Character recognition task. To ensure that participants were able to correctly match the faces presented during the dot-probe task with the biographical information taught at the beginning of the session, they completed a task following the dot-probe task where they were asked to match each face with its corresponding character type. This task

also allowed for identification of any group differences in character recognition ability. In the character recognition task, all 24 faces were presented for 500ms and participants were instructed to identify (from a list of written options) each face as trustworthy, neutral, or untrustworthy, based on the biographical information they had been taught about each character. To ensure that WS and MA participants were able to identify each face to the best of their ability, participants were provided with written options of 'good', 'neither good nor bad' and 'bad' in addition to the options of trustworthy, neutral and untrustworthy, to match the written descriptors provided when learning about the characters. Each trial was manually initiated by the experimenter. The character recognition task was always completed immediately after the dot-probe task to control for the possibility that it may affect attention allocation. The order of images was randomised across participants. Participants received a score out of eight (converted to a percentage) for each of the three categories used in the dot-probe task (trustworthy, neutral, untrustworthy).

Results

Character recognition task

The character recognition task was conducted to check that participants were indeed able to match each of the faces with the correct biographical information. Although not entirely necessary, as the dot-probe is an implicit task, we looked at character type recognition ability for comprehensiveness and also to determine whether the biographical information paired with each face stimulus was retained explicitly following the learning task. Additionally, as this paradigm has only been used in neurotypical adults to date, the character recognition task was deemed important to determine how WS individuals compared to neurotypical controls matched on chronological or mental age.

The average percentage of faces correctly identified for each character type are displayed separately for each group in Figure 2. Performance was significantly above

chance level (33.33%) for all stimuli (p <.0001), with the exception of the WS group when identifying neutral characters (p = .060). A repeated-measures ANOVA was conducted with character type (trustworthy, untrustworthy, neutral) as a within-subject factor and group (WS, CA, MA) as a between-subject factor. The results indicated a significant main effect of group, $F(2,39)=5.23$,$p=010$, partial $\eta^2=0.21$, and a significant main effect of character type recognition ability, $F(2,39)=5.23$, $p=.048$, partial $\eta^2=0.08$, but no significant group by character type interaction, $F(2,39)=1.43$, $p=.232$, partial $\eta^2=0.07$. Follow-up analyses were conducted between and within groups to explore these main effects. For all following analyses, the Bonferroni correction for multiple comparisons was applied where appropriate. *P*-values that were statistically significant at $p<.05$, but failed to reach significance at the corrected *p*-value are described as marginally significant. Cohen's *d* effect size estimates are reported for each pairwise comparison.

T-tests were conducted to determine whether character type recognition ability differed significantly between groups. An adjusted *p*-value of .025 (.05/2) was used to indicate statistical significance. Compared to CA-matched controls, WS participants were significantly less accurate at identifying trustworthy characters, $t(21.77)=2.53$, $p=.019$ ($d=0.95$) and neutral characters, $t(17.68)=2.65$, $p=.016$, ($d=1.01$), but not untrustworthy characters, $t(26)=1.13$,$p=.269$, ($d=0.43$). Compared to MA-matched controls, WS participants displayed no significant difference in their ability to identify trustworthy ($p=.924$), untrustworthy ($p=.219$) or neutral characters ($p=.309$). To ensure any trustworthy bias observed in the WS group was not reflective of their impaired recognition of these characters relative to CA-matched controls, we ran the main analyses both with and without trustworthy character recognition ability as a covariate. No differences in results were observed, therefore all further results are presented without the inclusion of this covariate.

T-tests were conducted to examine within-group differences in character type

recognition ability. An adjusted *p*-value of .017 (.05/3) was used to indicate statistical significance. The WS group displayed lower accuracy when identifying trustworthy characters compared to untrustworthy characters, $t(13)=–2.32$, $p=.037$ ($d=0.63$), and neutral characters compared to untrustworthy characters, $t(13)=2.55$, $p=.024$ ($d=0.89$), however these effects were only marginally significant. The WS group showed no significant difference in their ability to identify trustworthy characters and neutral characters, $t(13)=1.79$, $p=.097$ ($d=0.40$). No significant differences in character type recognition ability were observed in the CA or MA controls ($p>.25$).

Given that performance on the character recognition task was significantly lower in the WS group relative to the CA control group for trustworthy and neutral characters, Pearson correlation coefficients were used to investigate the relationship between accuracy rates for trustworthy and neutral characters, chronological age, verbal IQ and non-verbal IQ within the WS group. Within WS individuals, accuracy rates for trustworthy characters were not significantly related to chronological age ($r=.33$, $p=.257$), verbal IQ ($r=.27$, $p=.35$), or non-verbal IQ ($r=–.02$, $p=.940$). Similarly, accuracy rates for neutral characters were not significantly related to chronological age ($r=–.02$, $p=.936$), verbal IQ ($r=.10$, $p=.74$), or non-verbal IQ ($r=–.02$, $p=.937$).

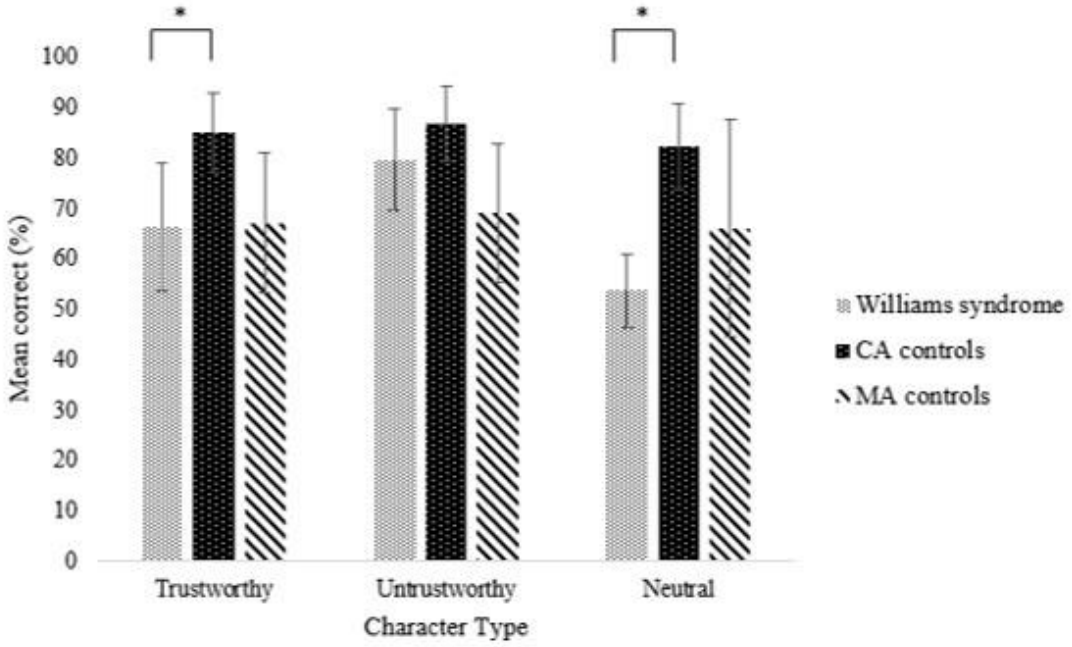

Figure 2: Mean percentage correct on character recognition task for Williams syndrome group, chronological age matched control group, and mental aged matched control group. Error bars represent ± 2 SEM.

Data preparation – dot-probe task

Following previous studies (e.g. see Dodd & Porter, 2010), trials with timing errors (trials with RTs of <200ms or >3000ms) and incorrect trials were removed and a mean and standard deviation were calculated for each participant. Further, in accordance with previous work (e.g. see McGrath et al., 2016) RTs more than 2 standard deviations above each participant's mean were removed. The mean percentage of trials for which RTs were removed was 7.12% for the WS group, 8.71% for the CA group and 12.01% for the MA group. The WS group did not differ from the CA group in the amount of RT data removed, $t(13)=-.68$, $p=.506$, nor did they differ from the MA group, $t(13)=-1.74$, $p=.105$.

Dot-probe task

Table 2 shows the mean and standard deviation of RTs for each group (WS, CA,

MA) on neutral, trustworthy-congruent, trustworthy-incongruent, untrustworthy-congruent and untrustworthy-incongruent trials. A congruent trial was identified as one in which the probe was located in the same position as the biographically salient stimuli (e.g. trustworthy or untrustworthy character), and an incongruent trial was identified as one in which the probe was located in the same position as the neutral stimuli. The mean and standard deviation for trustworthy and untrustworthy biases are also shown in Table 2. Trustworthy biases were calculated by subtracting the RTs for congruent trials from incongruent trials for trustworthy characters, and untrustworthy biases were calculated by subtracting the RTs for congruent trials from incongruent trials for untrustworthy characters. A positive score indicates a faster RT for congruent trials, suggesting a positive bias for those characters, while a negative score indicates a faster RT for incongruent trials, suggesting a negative bias for those characters.

Table 2

Mean (standard deviation) of reaction times (milliseconds) across groups on the dot-probe task

Condition	Controls		Williams Syndrome
	CA-Matched	MA-Matched	
	M (SD)	M (SD)	M (SD)
Neutral-neutral	360.8 (63.8)	499.3 (94.9)	502.9 (113.8)
Trustworthy-congruent	358.2 (62.5)	499.5 (99.4)	495.6 (125.5)
Trustworthy-incongruent	356.8 (57.7)	493.1 (103.9)	507.5 (130.3)
Untrustworthy-congruent	359.8 (62.8)	498.3 (95.4)	500.2 (119.2)
Untrustworthy-incongruent	360.2 (60.9)	492.4 (89.0)	498.9 (119.7)
Trustworthy bias	-1.5 (14.4)	-6.4 (22.2)	**11.9 (13.7)**
Untrustworthy bias	0.4 (12.4)	-5.8 (14.2)	-1.3 (16.1)

Bold = significant bias between and within groups.

Univariate analyses of variance were used to compare groups on mean bias scores. The mean RT for all trials was entered into analyses as a covariate due to a significant group difference on overall RT, $F(2,39)=9.90$, $p<.001$, with the CA group displaying faster

RTs compared to the WS (p=.001) and MA (p<.001) groups. No significant differences in overall RT were observed in the WS and MA groups (p=.914). Similarly, mental age was entered into analyses as a covariate, due to a significant negative relationship between overall trustworthy bias and mental age in the WS group only (r =–.64; p=.013). No significant effects of mental or chronological age on bias scores were found in either control group (p>.18). Likewise, no significant effects of gender on bias scores were found for the entire sample or for any group in isolation (p>.19). For the sample as a whole and each group in isolation, no significant correlations between trustworthy or untrustworthy bias scores and character type recognition ability were found (p>.14). Overall bias scores for each group are displayed in Figure 3.

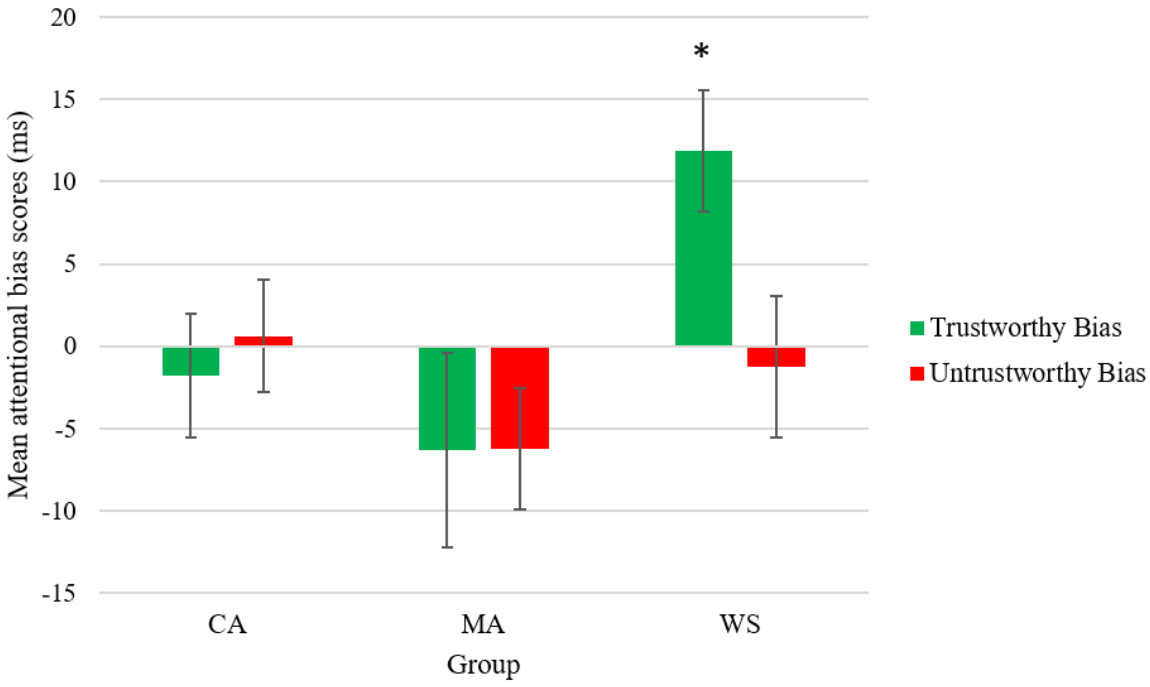

Figure 3. Demonstration of significant attention bias to trustworthy characters in WS group. Error bars represent ±2 SEM. * indicates between- and within-group significance at the p < .05 level.

Untrustworthy bias. When the mean attention bias scores for untrustworthy characters were compared between the WS, CA and MA groups, no difference was

observed, $F(2,37)=0.69$, $p=.505$, partial $\eta^2=0.04$. One sample *t*-tests indicated that the untrustworthy bias did not differ from zero for the participants in the WS group ($M=–1.26$ ms), $t(13)=–.29$, $p=.77$, those in the CA group ($M=0.41$ ms), $t(13)=.12$, $p=.904$, or those in the MA group ($M=–5.83$ ms), $t(13)=–1.54$, $p=.147$. Further, there was no evidence of a bias either toward or away from untrustworthy characters for any group, $\chi^2(2)=0.57$, $p=.751$.

Trustworthy bias. A comparison of the WS, CA and MA groups revealed a significant difference in mean attention bias towards trustworthy characters, $F(2,37)=4.08$, $p=.025$, partial $\eta^2=0.18$. Post hoc pairwise comparisons were conducted to compare the WS group to both control groups on bias towards trustworthy characters. An adjusted *p*-value of .025 (.05/2) was used to indicate statistical significance. Results indicated that WS participants displayed a significantly greater bias towards trustworthy characters compared to both CA, $t(26)=–2.51$, $p=.019$ ($d=0.95$), and MA controls, $t(26)=–2.62$, $p=.015$ ($d=0.99$). One-sample *t*-tests suggested that the trustworthy bias for the WS group ($M=11.88$ ms) differed significantly from zero, $t(13)=3.25$, $p=.006$, indicating that WS individuals displayed a clear attention preference for trustworthy characters. The avoidance bias for trustworthy characters observed in both the CA ($M= –1.45$ ms) and MA ($M= –6.36$ ms) groups did not differ from zero; $p > .30$, indicating a lack of attentional avoidance for trustworthy characters in both control groups. Additionally, comparing the number of participants in each group who displayed a bias toward or away from trustworthy characters revealed that only 3 of the 14 participants in the WS group exhibited a bias *away* from trustworthy faces, whereas 8 participants within the CA group and 9 participants within the MA group displayed this bias, $\chi^2(2)=5.92$, $p=.052$.

Trustworthy bias: Relationship with IQ. To explore whether the bias for trustworthy characters in the WS group was related to IQ, Pearson correlation coefficients were calculated. Following McGrath et al. (2016) we looked at verbal and non-verbal IQ

separately. With respect to verbal IQ, WS individuals displayed an average *W* score of 485.00 (*SD*=12.79), while average *W* scores for non-verbal IQ were 490.71 (*SD*=5.90). Converting these scores to standard scores resulted in an average verbal IQ of 69.00 (*SD*=7.81) and an average non-verbal IQ of 76.43 (*SD*=9.43). Following inspection of the scatterplots, data for one WS participant was removed, as they appeared to be an outlier with respect to verbal IQ, displaying substantially increased scores relative to the rest of the WS sample. See Appendix B for the graphical display of this relationship, both before and after removal of this participant. Following removal of this outlier, a moderate, marginally significant relationship between overall trustworthy bias and verbal IQ was observed, r=-.53, p=.062, indicating that a larger bias for trustworthy characters was associated with lower verbal ability. This pattern was not observed for non-verbal IQ, with no apparent relationship between overall trustworthy bias and non-verbal IQ, r=-.24, p=.425.

Trustworthy bias: Relationship with Anxiety. Given the exploratory nature of these analyses, alongside our small WS sample, we chose to investigate only the generalised anxiety (GAD) and social phobia subscales of the SCAS, as McGrath et al. (2016) reported a meaningful relationship between attention bias and these subscales only. WS individuals displayed an average score of 5.42 (*SD*=4.96) on the social phobia subscale of the SCAS and an average score of 6.75 (*SD*=5.29) on the GAD subscale of the SCAS. To explore whether the bias for trustworthy characters in the WS group was related to anxiety levels, as measured by scores on these subscales of the SCAS, Pearson correlation coefficients were calculated. No significant correlations between trustworthy bias scores and either GAD, (r =.15, p=.609) or social phobia, (r =-.001, p=.998) scores were found, indicating that there was no relationship between the trustworthy bias and anxiety symptoms in this WS sample.

Trustworthy bias: Capture versus disengage effects. These findings suggest an attention bias towards trustworthy characters in the WS group. Following Dodd and Porter (2010), further *t*-tests were conducted to explore whether this bias was due to attention capture or attention disengagement by comparing the neutral condition with the congruent and incongruent conditions. A significant difference between RTs on neutral trials and congruent trials indicates a capture effect, suggesting that the trustworthy character is capturing attention. In contrast, a significant difference between RTs on neutral trials and incongruent trials indicates a disengagement effect, suggesting difficulties in disengaging attention from the trustworthy character to respond to a probe in a different location. This analysis revealed a mean score of 7.24 ms (*SD*=19.00) for attention capture and a mean score of -4.64 ms (*SD*=21.76) for attention disengagement. One sample *t*-tests indicated that the capture score did not differ from zero, $t(13)=1.43$, $p=.177$, nor did the disengagement score, $t(13)=-.80$, $p=.439$. To examine whether there was any evidence of capture or disengagement effects in the TD control groups, these analyses were conducted for the MA and CA groups independently. None of the scores differed significantly from zero ($p>.19$).

To investigate within-syndrome variability in the trustworthy bias, z-scores were computed for the capture and disengagement raw scores. We were interested in the degree to which WS individuals displayed capture or disengage effects relative to the overall control sample. Raw scores from both control groups were pooled to calculate a population mean and standard deviation, which were then used to calculate individual capture and disengagement z-scores for the WS group. This calculation was similar to that performed by Krishnan, Bergstrom, Alcock, Dick, and Karmiloff-Smith (2015). A z-score of ≥ 1.645 represented a substantial effect of either attentional capture or disengagement for a WS individual. The cut-off of 1.645 was chosen as it corresponds to a one-tailed alpha level of .05. This was deemed suitable, since we were only looking at positive z-scores, (i.e.,

indicating that WS individuals were displaying larger effects relative to controls). Capture and disengagement z-scores for each WS participant are displayed in Figure 4. Results indicated capture effects for two WS individuals (14% of WS sample), with z-scores of 1.92 and 1.78, respectively, indicating that trustworthy characters were capturing the attention of these individuals. Disengagement effects were observed for two WS individuals (14% of WS sample), with z-scores of 2.19 and 4.14, respectively, suggesting difficulties in disengaging attention from trustworthy characters in these individuals. There was no overlap in these scores, indicating a pattern of attention allocation that was specific to individuals. Exploring these effects at the individual level indicates that 28% of the WS sample in this study displayed abnormalities in attention allocation for trustworthy characters, relative to both CA- and MA-matched controls. This individual variability may explain the lack of evidence observed for either capture or disengage effects at the group level.

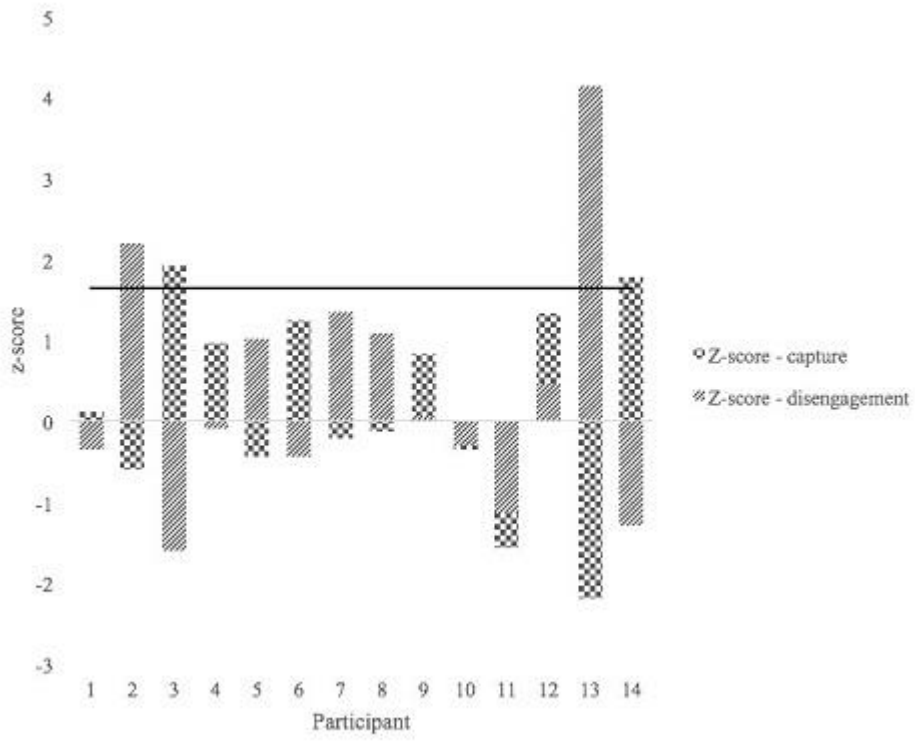

Figure 4. Capture and disengagement z-scores in WS individuals

Trustworthy capture and disengagement effects: Relationship with anxiety and IQ. In addition to exploring individual differences in capture and disengagement effects for trustworthy characters within the WS group, we were also interested in whether individuals who displayed strong capture or disengagement effects (denoted by a z-score ≥ 1.645) exhibited individual differences in their anxiety or IQ profile, relative to the rest of the WS group. Given the small number of WS individuals who displayed capture or disengagement effects, we limited these results to a visual inspection of the scatterplots.

Following visual inspection of the scatterplots, there was no apparent relationship between strong capture or disengagement effects and social phobia symptoms or GAD symptoms. While we found no evidence of a relationship between capture effects and verbal IQ, the WS individuals who demonstrated disengagement effects also displayed a lower verbal IQ, relative to the remainder of the WS cohort (see Figure 5). There was no apparent relationship between strong capture or disengagement effect and nonverbal IQ.

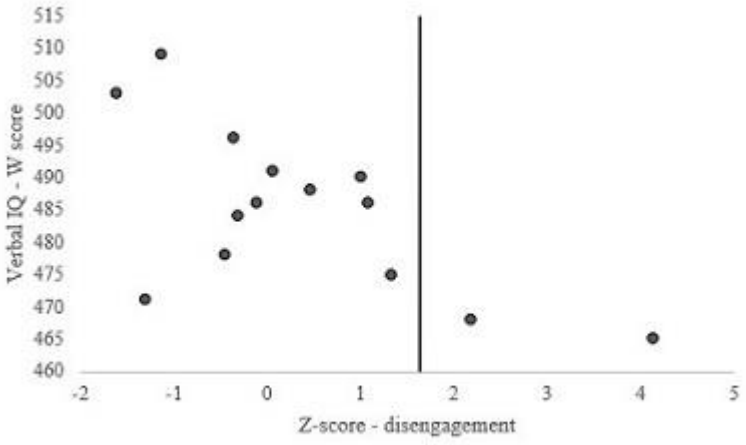

Figure 5. Relationship between disengagement effects and verbal IQ in WS individuals. Reference line is set at 1.645.

Discussion

The present study investigated allocation of attention to perceptually neutral faces that had been paired with positive (trustworthy) or negative (untrustworthy) biographical information in individuals with WS, as well as CA- and MA-matched neurotypical controls. As predicted, a within-group attention bias for trustworthy characters was observed in the WS group, but not in either control group. Additionally, in line with our hypothesis, compared to both control groups, the WS individuals displayed a specific attention bias towards trustworthy characters, on average. These findings were supported by large effect size estimates. As predicted, there was no evidence of a within-group attention bias for untrustworthy characters in any of the groups, nor was there evidence for a between-group bias for untrustworthy characters.

The finding of a significant trustworthy bias in the WS group is consistent with prior accounts of a bias towards positive (happy) faces in WS individuals when using a dot-probe task, compared to CA- and MA-matched neurotypical controls (Dodd & Porter, 2010). However, when considering the mechanisms underlying this bias, our findings did not suggest that the WS group on the whole experienced difficulties disengaging attention from trustworthy characters. This finding does not align with the argument presented by Riby et al. (2011) where it was suggested that WS individuals experience difficulty in shifting their attention away from faces, rather than faces capturing the attention of these individuals. Exploring the mechanisms driving the trustworthy bias at the individual level revealed some evidence of within-syndrome heterogeneity. While some WS individuals experienced difficulties disengaging attention from trustworthy characters, as originally anticipated, others appeared to show the opposite effect, with the trustworthy characters capturing the attention of those WS individuals.

Following from the recent findings of McGrath et al. (2016), where a positive attention bias was mediated by anxiety and level of IQ in a large cohort of WS individuals,

a secondary aim of this study was to investigate the relationship between the trustworthy bias, IQ and anxiety in the WS group. Given the small sample size, caution is required when interpreting these results. However, despite the small sample size, it should be noted that the verbal IQ, non-verbal IQ and anxiety results reported here are largely consistent with previous findings. Verbal IQ scores were within the mild to moderate impairment range. While the non-verbal IQ scores reported here may appear higher than one would expect given the general WS cognitive profile, this is likely due to the absence of a construction component in the subtest we used to attain an estimate of non-verbal IQ. Indeed, performance on the equivalent version of this subtest in the Woodcock-Johnson Tests of Cognitive Ability-Revised has been found to be a cognitive strength in some WS individuals (Porter & Coltheart, 2005). Similarly, anxiety scores in this study are largely consistent with previous research on anxiety in WS where the SCAS has been used (Dodd et al., 2009; McGrath et al., 2016), with WS individuals displaying higher scores on the GAD subscale relative to the social phobia subscale, suggesting that this is a representative WS sample in terms of anxiety.

Whilst we found evidence of a moderate, negative relationship between trustworthy bias and verbal IQ, such that WS individuals who displayed a larger trustworthy bias tended to also have a lower verbal IQ, no associations were observed between trustworthy bias and nonverbal IQ or anxiety symptoms. It is possible that the lack of a relationship between trustworthy bias and nonverbal IQ in the current study may be explained by the task used to assess nonverbal IQ. Where McGrath et al. (2016) used a task of nonverbal reasoning to measure nonverbal IQ, a matrices subtest from the Kaufman Brief Intelligence Test–2nd Edition (Kaufman & Kaufman, 2004), the nonverbal task used in the current study measured visual-spatial thinking. It may be that higher order (executive functioning) abilities are related to the attention bias for positive social stimuli in WS, rather than purely visual-spatial skills.

Moreover, strong capture and disengagement effects were found to be differentially related to verbal IQ. While no relationship between attention capture and verbal IQ was observed, these preliminary results suggest that there may be a link between difficulties disengaging attention from positive social stimuli and verbal IQ, with the WS individuals who displayed strong disengagement effects also displaying lower verbal IQ, relative to the rest of the WS cohort. Given the small number of WS individuals who displayed large capture or disengagement effects (28% of WS sample), no formal statistical analyses were conducted on this data, with relationships inferred following visual inspection of scatterplots. Overall, these findings align with those of McGrath et al. (2016), suggesting that the attention bias for positive faces is related, in some capacity, to intellectual ability. Given these preliminary findings, and their concordance with McGrath et al. (2016), further investigation of attention patterns to positive social stimuli in WS, with an emphasis on individual differences in attention capture and disengagement, and their relationship to IQ and anxiety in a larger sample of WS individuals is warranted.

While findings from the character recognition task suggest that WS individuals were less accurate at identifying trustworthy and neutral characters relative to CA-matched neurotypical controls, it is worthwhile noting that these responses do not correspond to accuracy rates during the biographical face learning task, where all WS participants were able to identify biographical faces at a level of at least 80 percent accuracy. A possible explanation for this finding may lie in the attentional demands of the character recognition task. During this task faces were only presented for 500ms, to match the presentation duration of stimuli during the dot-probe task. Although no inattention was observed in WS individuals during this task, it was completed immediately after the dot-probe task, and as such, it is possible that this finding reflects attention difficulties within the WS group, rather than impairments in learning the biographical faces. However, a more likely possibility is the rapid presentation of stimuli, which would be difficult for the WS

individuals to process given their slower processing speed and intellectual disability.

Overall, the current findings are consistent with previous results using positive social-perceptual stimuli (Dodd & Porter, 2010; Goldman et al., 2016), indicating that the positive bias in WS is more pervasive than initially thought, and continues to operate when top-down processing is used. Taken in conjunction with the findings of Godbee and Porter (2013), these results provide evidence for the presence of a top-down positive bias in WS, as well as the bottom-up positive bias that has been found using perceptual stimuli. Godbee and Porter (2013) explored the extent to which WS individuals made negative attributions of intention when presented with ambiguous social scenarios. Comparing WS individuals to typically developing controls matched on either chronological age or developmental age, the authors found that WS individuals were less likely to attribute negative intentions to these scenarios when compared to their same-age peers. Taken together, these findings suggest that the positive bias in WS appears to apply to face stimuli that are paired with positive biographical information, despite being perceptually neutral, in addition to social scenarios that are ambiguous and could be interpreted in a number of ways. This positive bias could be instrumental in the development of the hypersociability seen in WS, and could help explain their atypical daily social behaviours. These findings also suggest that both bottom-up and top-down processes may be at play in the development of the WS social phenotype.

It is plausible that the attention bias for trustworthy characters displayed by WS individuals is a consequence of neurological dysfunction. To date, one study has used this biographical learning paradigm when looking at amygdala reactivity to faces in neurotypical adults (Charmet-Mougey et al., 2012). The authors found that the biographical knowledge associated with the faces influenced amygdala reactivity, suggesting that the amygdala may be affected by emotional memory in neurotypical adults. Whilst brain activity was not recorded in the current study, these results do show

similarities with prior neuroimaging findings, where atypical amygdala and frontal reactivity has been observed in response to positive social-perceptual faces (Haas et al. 2009; Meyer-Lindenberg et al., 2005). Commenting on the role of the central nucleus of the amygdala in attention processing, Haas et al. (2009) suggested that the increased reactivity in this region in WS individuals might represent a neural substrate for the increased attention to social stimuli. Likewise, given the evidence of abnormal frontal lobe reactivity in response to social stimuli (Mimura et al., 2010), recent research has proposed that this area represents an additional neurological substrate of the WS social phenotype (Little et al., 2013). Given previous findings that support a positive attention bias in WS when social-perceptual stimuli are used and bottom-up processing is employed (Dodd & Porter, 2010; Goldman et al., 2016), coupled with the current findings which suggest that this positive attention bias continues to occur when stimuli are biographically salient and top-down processing is used, it is plausible that both amygdala and frontal lobe dysfunction have cascading effects on attention allocation, consequently contributing to the social phenotype of WS.

Limitations and future directions

While these results provide evidence that the attention bias for positive social stimuli in WS extends beyond social-perceptual stimuli, certain limitations must be addressed. Although the WS sample recruited for the current study is equivalent in size to other studies in this area (e.g. see Dodd & Porter, 2010; Goldman et al., 2016), it is still a relatively small sample, and did not allow for a comprehensive investigation of within-syndrome heterogeneity, as seen in McGrath et al. (2016). Administering the dot-probe task using the face stimuli developed for this task to a larger number of WS participants would enable us to further investigate how attention to these stimuli may systematically vary as a result of cognitive ability and anxiety symptomatology. A larger sample would also help to delineate the nature of the positive attention bias in this population, and would

assist in determining whether this bias is due to positive stimuli capturing the attention of WS individuals, as opposed to difficulties disengaging with positive stimuli, or whether the nature of the bias differs between individuals. However, it is worth noting that even with a smaller sample, large effect sizes were observed (Cohen, 1992), highlighting the practical and clinical significance of the current findings.

Future studies would benefit from an investigation of the neurological and physiological responses to the biographical face stimuli used here, to further our understanding of the WS positive bias. Such research would extend existing findings (Haas et al., 2009; Jarvinen et al., 2015) and would indicate whether the bias for positive biographical faces reported here at the attentional level is also found at the neural level, via amygdala and frontal lobe dysfunction, and the physiological level, via a lack of habituation to biographically trustworthy faces. Similarly, future research exploring the attentional processes underlying the WS positive bias would benefit from the simultaneous measurement of eye movements whilst conducting a dot-probe task. This would allow for a more comprehensive investigation of online attention patterns when looking at social stimuli in WS, and may address some of the criticisms inherent in the dot-probe task (Waechter et al., 2013). Our research team is currently using functional magnetic resonance imaging and eye-tracking to further explore neurological and attentional responses to these biographical face stimuli in WS individuals.

Future research in this field should utilise cross-disorder comparisons. Exploring attention patterns using stimuli that are biographically salient, as opposed to perceptually salient, in disorders where increased social approach is typical and where social avoidance is common and an increased vigilance to threat is observed, would provide a valuable insight into the attentional mechanisms employed when processing perceptually neutral, but semantically salient faces. This would also contribute to our understanding of how attention is allocated and modulated in disorders with contrasting social phenotypes.

Practical implications

The current findings have practical implications for the development of interventions for WS individuals. Intense eye gaze towards faces has been observed anecdotally in WS (Mervis et al., 2003). This increased eye gaze can be disconcerting, and may contribute to the social isolation WS individuals experience, as reported by parents and caregivers (Davies, Udwin, & Howlin, 1998). The current findings suggest that some WS individuals experience difficulties when disengaging their attention from faces. For those individuals, intervention programs designed to assist in disengaging attention from faces and eyes may be an effective intervention strategy, and may improve the day-to-day social functioning of WS individuals with attention disengagement difficulties.

Further, the current findings suggest that WS individuals are able to use semantic (top-down) processing when automatically allocating their attention to faces. Future interventions focused on stranger danger training may benefit from teaching WS individuals negative schematic or biographical information about strangers, to help discourage approach behaviours in daily life. When considering stranger danger awareness in WS individuals, Riby et al. (2014) found that young individuals with WS displayed a decreased awareness of stranger danger, relative to neurotypical controls matched on developmental age. Additionally, the authors reported that WS individuals explicitly stated that they would approach and engage in interactions with strangers (Riby et al., 2014), highlighting the importance of effective interventions in this area.

Finally, the individual variability observed in the current study highlights the importance of developing individually tailored interventions for use in WS. Given the current findings, alongside previous findings of heterogeneity in attention bias (McGrath et al., 2016), cognitive abilities (Porter & Coltheart, 2005) and psychopathology (Porter, Dodd, & Cairns, 2009) in WS, the importance of individually tailored interventions cannot be over emphasised. Such heterogeneity indicates that it is important to obtain each WS

individual's social profile prior to an intervention, to better understand individual patterns and to identify the areas to target for optimal treatment. Further, a multidisciplinary approach towards intervention is likely to be of benefit to WS individuals, with an understanding of the cognitive and psychological profile of an individual likely to bolster the effectiveness of treatments for social dysfunction. An individually tailored, multidisciplinary approach towards interventions would enable WS individuals experiencing social difficulties to receive a holistic intervention that is designed to treat their unique pattern of strengths and impairments, thereby maximising the likelihood of success and overall improvement in their day-to-day social functioning.

Conclusion

The present research provides evidence that the positive attention bias for happy faces seen in WS extends beyond social-perceptual stimuli. The results from this study indicate that WS individuals preferentially allocate their attention towards faces that they have previously learnt to associate with positive biographical information, even when the faces are perceptually neutral. This finding suggests that WS individuals are able to learn important information about faces, and show a tendency to apply this information in an implicit attention task, displaying similar biases in attention to those observed when social-perceptual faces are presented. This study provides support for the idea that the positive pro-social bias often seen and commented on in WS is more widespread than previously anticipated, and is not limited to a social-perceptual context. It is argued that both bottom up (e.g. perception of facial expressions) and top down (e.g. biographical information) processes drive the atypical positive attention bias in WS.

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Paper 1 – Appendix A

Vignettes for biographical characters

Vignette used for Trustworthy Characters

You will now see some pictures of some people who are very good and extremely trustworthy. They come from a very good planet where people are very kind to each other. These people help each other out all the time, give money to charity and are friendly to everyone. They will care for you if you are sick and will look after you in hard times. These are the sort of people you would love to be friends with, and you would be very happy to visit the planet they come from!

Vignette used for Neutral Characters

You will now see some pictures of people who are neither trustworthy nor untrustworthy – they are neither good nor bad. They come from a planet where people are not unkind to each other, but they do not make efforts to be kind either. They are not likely to steal from each other, but they are not likely to help each other out either. They are the sort of people that you wouldn't avoid, but wouldn't love to be friends with either. You wouldn't really be bothered whether or not you visited the planet they came from!

Vignette used for Untrustworthy Characters

You will now see some pictures of people that are extremely bad and very untrustworthy. They come from a very bad planet where people are extremely unkind. These people lie to each other, steal from each other, and often cheat when playing games or doing exams at school. They often physically fight with each other. They are the sort of people that you would not want to be friends with, and you would not want to visit the planet they come from!

Paper 1 – Appendix B

Relationship between verbal IQ and trustworthy bias – WS participants

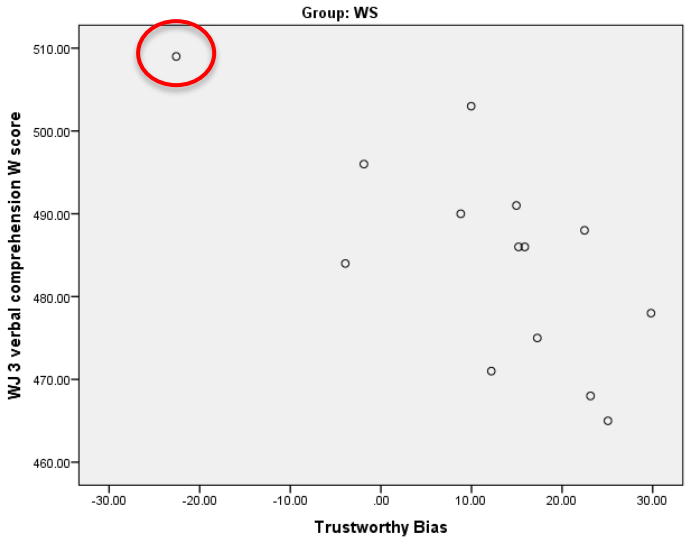

Figure B1. Relationship between verbal IQ and trustworthy bias before removal of outlier (outlier circled on scatter plot). r = -.667, p = .009

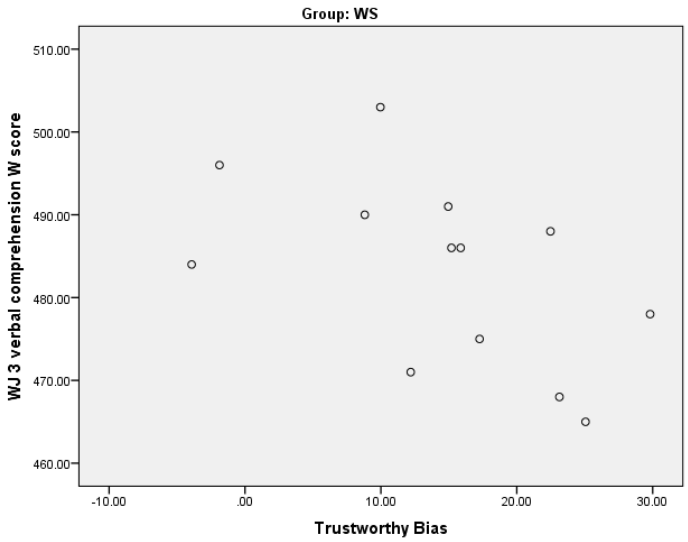

Figure B2. Relationship between verbal IQ and trustworthy bias after removal of outlier. r = -.531, p = .062

Paper 2

Attention for Faces in Williams syndrome, Autism Spectrum Disorder and Social Anxiety Disorder: The Role of Biographical Information

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Abstract

Introduction: Abnormalities in attention for faces are observed in Williams syndrome (WS), Autism Spectrum Disorder (ASD) and Social Anxiety Disorder (SoAD). A comparison of attention for biographical faces was conducted using traditional (attention bias) and novel (attention bias variability) indices to explore group differences in attention bias.

Method: 72 participants (14 WS, 14 ASD, 15 SoAD, 29 neurotypical controls) learnt to associate perceptually neutral faces with trustworthy, neutral, or untrustworthy biographical information, before completing a dot-probe task with the same faces.

Results: The WS group displayed an increased attention bias for trustworthy characters, coupled with increased attention bias variability towards trustworthy characters and increased attention bias variability away from untrustworthy characters. Decreased attention bias variability for trustworthy characters was observed in the ASD group. The SoAD group displayed an elevated attention bias for untrustworthy characters.

Conclusions: Findings indicated that the differing social phenotypes seen in WS, ASD and SoAD are also observable at the attentional level when biographical faces are used. Findings highlight the need to incorporate biographical information in intervention programmes to improve social functioning across these disorders.

Attention for Faces in Williams syndrome, Autism Spectrum Disorder and Social Anxiety Disorder: The Role of Biographical Information

Introduction

Impairments in social functioning are present in many conditions, including neurodevelopmental and anxiety disorders. There is a large body of research considering the syndrome-specific and syndrome-shared mechanisms that give rise to these impairments (e.g., see Hofmann, Boettcher, & Wu, 2015; Plesa Skwerer, 2017). One such mechanism is attention for faces. Attention for faces differs across disorders and, at face value, tends to complement the social features of particular conditions. For example, in Williams syndrome (WS), where hypersociability and social approach are common, studies exploring attentional bias, including eye-tracking and dot probe paradigms show increased attention towards positive faces (Goldman et al., 2016; Kirk, Hocking, Riby, & Cornish, 2013). In contrast, in Autism Spectrum Disorder (ASD), which is characterised by reduced social interest and social avoidance, eye-tracking studies indicate that individuals spend less time attending to faces relative to neurotypical controls (Chita-Tegmark, 2016). Further, in Social Anxiety Disorder (SoAD), where a fear of negative evaluation contributes to social difficulties, eye-tracking and dot-probe studies reveal increased attention towards threatening faces (Bantin et al., 2016; Lazarov, Abend, & Bar-Haim, 2016). Convergent with these findings, functional neuroimaging studies have also demonstrated amygdala activity consistent with the direction of attentional bias in each of these disorders (e.g., Aoki, Cortese, & Tansella, 2015; Binelli et al., 2014; Haas & Reiss, 2012).

While there are clear differences in attention for faces across these conditions, the resulting functional impairments, that is, impairments in social behaviour and in interpersonal relations are similar (Aderka et al., 2012; Fisher & Morin, 2017; Vivanti & Salomone, 2015). Additionally, in WS impaired stranger-danger awareness is observed

both anecdotally and experimentally (Riby, Kirk, Hanley, & Riby, 2014) and has been linked with increased attention for positive faces. These difficulties persist across the lifespan, contributing to poor social and mental health outcomes for affected individuals.

Atypical attention to faces in WS, ASD and SoAD

Atypical attention towards faces is believed to contribute to social dysfunction in WS (McGrath et al., 2016), ASD (Bush & Kennedy, 2015) and SoAD (Wong & Rapee, 2016). In an effort to understand these attention abnormalities in response to faces, previous research has investigated attention biases to faces using, among other methodologies, variations of the dot-probe paradigm (Bar-Haim et al., 2007). The dot-probe paradigm involves the brief, simultaneous presentation of a salient stimulus and a neutral stimulus. This is followed by the appearance of a probe, in the place of either the salient or neutral stimulus, which participants must identify and respond to. Faster response times to the probes that replace the salient stimulus reflect an attention bias towards the salient stimulus. A typical manipulation of the paradigm involves alternating the expression of the salient face stimuli to represent socially pleasant versus socially threatening material. The sequence of events in this variant of the dot-probe task is illustrated in Figure 1. Taken together, the literature that has utilised this paradigm suggests that there are abnormalities in attention for faces across a wide range of neurodevelopmental, neurological, and mental health conditions, including WS, ASD and SoAD (Evans, Walukevich, & Britton, 2016; García-Blanco, Yáñez, Vázquez, Marcos, & Perea, 2017; Goldman et al., 2016). Further, this bias appears to be modulated by face valence (Bantin et al., 2016; Plesa Skwerer, 2017).

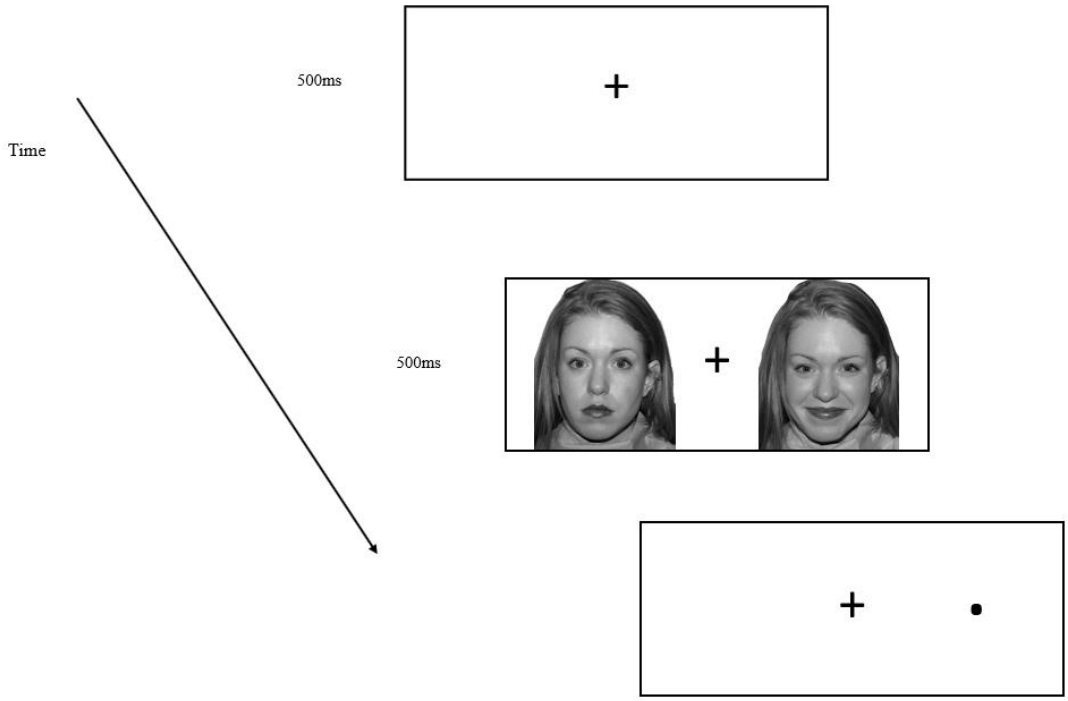

Figure 1. Sequence of events in a dot-probe task designed to assess attention biases for emotional faces.

In WS, a neurodevelopmental disorder caused by a microdeletion on chromosome 7 (Ewart, 1993), heightened social approach and an increased interest in people, even strangers, is often observed (Jones et al., 2000; Thurman & Fisher, 2015). Consistent with this social profile, people with WS display increased attention to faces (Mervis et al., 2003). Increased attention for faces has been observed in WS using numerous experimental paradigms. Results from eye-tracking studies suggest that people with WS experience difficulty when disengaging their attention from faces (Riby & Hancock, 2009) , while functional neuroimaging paradigms have revealed increased amygdala reactivity to happy faces coupled with attenuated amygdala activity to fearful faces in this disorder (Haas et al., 2009). When measured using the dot-probe paradigm, this increased attention appears to be specific for positive (happy) faces, with research revealing a significant attention bias towards happy faces in WS individuals compared to neurotypical individuals matched on chronological or mental age (Dodd & Porter, 2010), as well as individuals with Down

syndrome (Goldman et al., 2016).

In contrast to the hypersociability seen in WS, people with ASD typically display a social profile characterised by hyposociability and social withdrawal (Barak & Feng, 2016). The evidence considering attention biases for faces in this group has been somewhat mixed, perhaps to some degree due to differences in methodologies. A recent meta-analysis of eye-tracking studies reported that, relative to neurotypical controls, people with ASD spend less time looking at social stimuli (Chita-Tegmark, 2016). Further, a recent review of functional neuroimaging studies suggests that the atypical processing of emotional faces seen in ASD is associated with hypoactivation of certain subcortical structures, including the amygdala (Aoki et al., 2015), although neuroimaging findings are mixed (Tottenham et al., 2014). When using the dot-probe paradigm to assess attention for faces in ASD individuals, there is a lack of consistency across studies.

Where earlier studies using the dot-probe paradigm reported no differences in attention bias towards or away from threatening faces when comparing individuals with ASD to same-aged neurotypical controls (Hollocks et al., 2013; May et al., 2015), recent findings indicate that attention for faces in ASD may vary as a function of stimulus presentation duration. Garcia-Blanco and colleagues found that relative to neurotypical controls, ASD individuals displayed an attention bias away from threatening faces when the faces were presented for a longer period of time (1500ms), but not when they were presented for shorter periods (500ms) (Garcia-Blanco et al., 2017). The authors noted that stimulus presentation duration differs across methodologies and tasks and posited that this may help explain the discrepancies in findings when looking at attention for faces in ASD.

Distinct from neurodevelopmental disorders such as WS or ASD, SoAD is a mental disorder and one of the most common anxiety disorders, affecting 8.4% of Australians at some point in their lives (Crome et al., 2015). One of the core features of SoAD is the fear of being evaluated negatively by others in social situations, often resulting in avoidance of

social situations (Hofmann et al., 2015). A recent review considering attention for faces in SoAD using eye-tracking methodologies suggests that people with SoAD generally avoid looking at the eye region of faces in an emotion-specific manner, such that the effect is largest for angry faces (Chen & Clarke, 2017). Consistent with this behavioural avoidance, a meta-analysis from Binelli and colleagues suggests that threatening emotional expressions elicit hyperactivation in the amygdala in SoAD individuals, compared to neurotypical controls (Binelli et al., 2014).

However, as is the case with the ASD literature, the evidence investigating abnormalities in attention for faces in SoAD when using the dot-probe paradigm has been mixed. Where some studies report an attention bias for threatening faces in people with SoAD relative to same-aged neurotypical controls (Klumpp & Amir, 2009), others have found no evidence for such a bias (Schneier et al., 2016). In an attempt to disentangle these discrepancies Bantin et al. (2016) conducted a meta-analysis, focusing on those studies that utilised the dot-probe paradigm to measure attention bias for faces in SoAD. Overall, the authors found that SoAD individuals tended to display an attention bias towards threatening faces relative to same-aged neurotypical controls, but caution that effect sizes are generally small to medium. Taken together, the research suggests that individuals with SoAD exhibit abnormal attention to faces, with a tendency to show an attention bias for threatening faces.

Based on the literature outlined above, attention for faces seems to be atypical in WS, ASD and SoAD. These abnormalities in attention have been assessed using a number of experimental methodologies, including the dot-probe paradigm. While the majority of prior studies employing the dot-probe paradigm have assessed attention towards or away from faces using a single overall attention bias score, researchers have recently begun to consider the intra-individual variability of the attention bias, rather than relying solely on the overall attention bias score (e.g. see Iacoviello et al. (2014)). This variability, termed

attention bias variability, is thought to reflect fluctuations in attentional control (Iacoviello et al., 2014). Increased attention bias variability has been theorised as reflecting heightened attention towards the salient face at some points during the testing session, coupled with heightened attention away from the salient face at other points (Gladwin, 2016). Where overall attention bias scores assume that attention bias is a stable construct that can be expressed by the average value of reaction times over many trials, attention bias variability presents attention bias as a dynamic construct, suggesting that the attention bias of a given individual can fluctuate across trials within a session, both towards and away from salient stimuli. This measure has been proposed as a complement to the commonly used overall attention bias scores, given its superior psychometric properties (Price et al., 2015).

Existing evidence suggests that increased attention bias variability for trauma-related words is associated with increased symptom severity in posttraumatic stress disorder (Swick & Ashley, 2017), suggesting that it may be a useful measure to explore in other disorders, such as WS, ASD and SoAD, where abnormal attention bias variability to faces may be related to severity of social impairment. To the best of our knowledge attention bias variability has not yet been explored in WS or ASD. With respect to SoAD, a recent study reported that attention bias variability did not differ between SoAD individuals and neurotypical controls (Schneier et al., 2016). However, the authors note that overall attention bias scores for threatening faces also did not differ between groups, commenting that the clinical heterogeneity of their SoAD sample may have prevented detection of the small to moderate effect sizes previously reported by Bantin et al. (2016). Of interest, while the authors found that attention bias variability for threatening faces was not associated with severity of social avoidance symptoms, overall attention bias scores for threatening faces were related to increased social avoidance symptoms within SoAD individuals, suggesting a potential link between heightened attention for threatening faces and increased social anxiety symptomatology (Schneier et al., 2016).

Despite the promising psychometric properties of attention bias variability relative to overall attention bias scores, it is currently unclear which processes are driving the observed fluctuations in attention. A recent simulation study with randomly generated data found that increased attention bias variability in the absence of an overall attention bias was more likely to reflect measurement error, as opposed to actual variability in attention bias (Kruijt, Field, & Fox, 2016). Further, while Swick and Ashley (2017) reported increased attention bias variability for threatening stimuli (but no overall attention bias) in individuals with posttraumatic stress disorder compared to controls, they found that this was strongly correlated with increased reaction time variability. Ultimately, the authors suggested that in the absence of an overall attention bias, increased attention bias variability may reflect more general deficits in attention processes that are required to maintain stable performance for the duration of the dot-probe task, in addition to variabilities in attention bias. While these findings highlight the potential shortcomings of attention bias variability, taken together, they suggest that it is a novel measure that can be used to assess fluctuations in attention over the course of a testing session. Given the abnormalities in attention for faces seen in WS, ASD and SoAD outlined above, an investigation of attention for faces using both overall attention bias scores and attention bias variability across WS, ASD and SoAD is warranted.

When investigating attention for faces in people with WS, ASD and SoAD, much of the research to date that has utilised the dot-probe paradigm has focused on abnormalities in attention within a single disorder. While there are some instances of cross-disorder comparisons (see Goldman et al. (2016); Schneier et al. (2016)), research has largely employed comparison groups comprising neurotypical controls matched to the clinical group on chronological or mental age. Given their contrasting overt social features, a cross-disorder comparison of WS, ASD and SoAD provides an opportunity to directly examine disorder-specific differences in attention for faces. Prior studies employing

alternative methodologies, such as eye-tracking and functional neuroimaging have utilised cross-disorder comparisons to explore emotional face processing in WS and ASD individuals (Riby, Doherty-Sneddon, & Bruce, 2008) , ASD and SoAD individuals (Wong, Beidel, Sarver, & Sims, 2012), and more recently WS and SoAD individuals (Binelli et al., 2016), however no research to date has investigated attention for faces in WS, ASD and SoAD using a dot-probe paradigm. Such a comparison will further our understanding of how abnormalities in attention for faces can contribute to the social dysfunction in each disorder.

Overall, the above literature suggests that attention for faces in WS, ASD and SoAD is abnormal and modulated by face valence. Research to date has largely focused on valence by manipulating emotional expressions. While emotional expressions are important in helping us navigate the social world, they are not the only feature we use when making decisions about whether to engage in or avoid social interactions (McCarthy & Skowronski, 2011). For example, there are often person-based, biographical details and schemas that we use to decide who we will look at, pay attention to and interact with socially (Cassidy & Gutchess, 2015). Building on the research that suggests some abnormalities in attention for threatening social-perpetual faces in WS, ASD and SoAD, an exploration of attention for faces associated with positive and threatening biographical information is warranted in these groups.

Investigating attention to faces in WS, ASD and SoAD – beyond social-perceptual stimuli

While the majority of research into WS, ASD or SoAD has explored attention to positive and threatening faces by manipulating emotional expression, we manipulated biographical information in an effort to investigate attentional responses to positive and threatening biographical faces. Given the similar social functioning deficits seen in WS, ASD and SoAD, despite disparate social profiles, a cross-disorder comparison of attention

for biographical faces will better inform our understanding of how abnormalities in attention for faces may contribute to eventual impairments in social functioning. Participants were required to use top-down processing (learned biographical information) rather than bottom-up (perceptual) processing. We explored group differences in attention for trustworthy characters – perceptually neutral face stimuli paired with trustworthy biographical information and untrustworthy characters – perceptually neutral face stimuli paired with untrustworthy biographical information. There was also a neutral condition comprised of perceptually neutral face stimuli paired with neutral biographical information.

Our primary aim was to compare attention for trustworthy and untrustworthy characters in WS, ASD and SoAD groups, and neurotypical controls. Based on previous research (Goldman et al., 2016), we predicted that WS individuals would show a larger attention bias for trustworthy characters compared to ASD and SoAD individuals, as well as neurotypical controls matched on chronological or mental age. No other group differences were hypothesised for trustworthy characters. Following prior research (Bantin et al., 2016) we predicted that SoAD individuals would show a larger attention bias for untrustworthy characters compared to neurotypical controls (matched on chronological age). Likewise, we predicted that the attention bias for untrustworthy characters would be significantly larger in the SoAD group relative to the WS group. Previous research indicates no attention bias towards or away from threatening faces in ASD individuals when stimuli are presented for short (500ms) durations (Garcia-Blanco et al., 2017; May et al., 2015). As such, no differences in attention bias for untrustworthy characters were predicted in ASD relative to neurotypical controls. No other group differences were hypothesised for untrustworthy characters.

A secondary aim of the current study was to investigate differences in attention bias variability for trustworthy and untrustworthy characters in WS, ASD and SoAD groups, as

well as in neurotypical controls. Following from Schneier et al. (2016) we were interested in exploring the extent to which attention to trustworthy and untrustworthy characters fluctuated over the testing session. Price et al. (2015) have recommended that measures of attention bias variability be used in addition to overall attention bias scores when using the dot-probe task, given the superior reliability of this measure. Given that attention bias variability has not yet been utilised in WS nor ASD populations, we did not have any direct hypotheses with regards to group differences on this measure. However, following from the findings of Swick and Ashley (2017) we did predict that increased attention bias variability in the absence of an overall attention bias for trustworthy or untrustworthy characters would be related to increased reaction time variability.

Method

Participants

The study included 15 participants each with WS, ASD, SoAD, and 30 neurotypical participants (15 matched to WS participants on mental age and 15 matched to all clinical groups on chronological age). These participants were recruited for a series of studies, as reported in Boulton and Porter (2017); Boulton et al. (2018b, 2018c, 2018d). A mental age comparison group was included to accommodate the intellectual disability in the WS group. Neither the ASD nor SoAD group displayed evidence of intellectual disability. A measure of verbal and spatial abilities was obtained for all participants using the Woodcock-Johnson Tests of Cognitive Ability – 3rd Edition (WJ-III COG; Woodcok, McGrew, & Mather, 2001) (see below for details). The study was approved by the Macquarie University Human Research Ethics Committee. Informed consent was obtained from the participants or their parents/caregivers, as appropriate.

Williams syndrome group. WS participants (8 male, 7 female) were recruited through Williams Syndrome Australia Limited. All participants with WS had a positive fluorescent in situ hybridisation (FISH) test showing deletion of the elastin gene at 7q11.23

(Fryssira et al., 1997). Exclusionary criteria for the WS group included: 1) co-morbid neurological condition or insult; 2) a history of developmental delay that was secondary to the primary diagnosis of WS; or 3) a clinical diagnosis that was secondary to the primary diagnosis of WS. No participants met exclusionary criteria. Verbal ability standard scores using the Verbal Comprehension subtest from the WJ-III COG ranged from 56 to 91 (*M*=69.93; *SD*=9.62) and spatial-perceptual ability standard scores using the Spatial Relations subtest from the WJ-III COG ranged from 55 to 90 (*M*=75.73; *SD*=9.48).

Autism spectrum disorder group. ASD participants (9 male, 6 female) were recruited through Autism Spectrum Australia. Participants had received a formal diagnosis of Autism or Asperger syndrome from a clinical psychologist and met criteria for ASD according to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5; American Psychiatric Association, 2013), confirmed by study authors MP or QW, qualified and registered psychologists. ASD participants also met clinical cut-offs for deficiencies in reciprocal social behaviour on the Social Responsiveness Scale-2nd Edition (SRS-2; Constantino & Gruber, 2012). For child ASD participants, the School-Age Form was completed by parents, while adult ASD participants completed the Adult Self-Report Form. Further, the Ritvo Asperger and Autism Diagnostic Scale-Revised (RAADS-R; Ritvo et al., 2011) was administered to adult ASD participants. The RAADS-R is a self-report diagnostic measure, designed for assisting the diagnosis of ASD in adults with average intelligence. Consistent with a diagnosis of ASD, scores for all participants were above the diagnostic threshold of 65 on this measure (Ritvo et al., 2011). Exclusionary criteria for the ASD group included: 1) co-morbid neurological condition or insult; 2) a history of developmental delay; 3) intellectual disability; or 4) a clinical diagnosis that was not related to the primary diagnosis of ASD. No participants met exclusionary criteria. Verbal ability standard scores using the Verbal Comprehension subtest from the WJ-III COG ranged from 84 to 125 (*M*=107.57; *SD*=12.19) and spatial ability standard scores

using the Spatial Relations subtest from the WJ-III COG ranged from 94 to 133 (*M*=110.29; *SD*=9.42).

Social anxiety disorder group. SoAD participants (1 male, 14 female) were recruited through Macquarie University via advertisements placed around campus (*N*=8) and through the Centre for Emotional Health, a research and treatment clinic focused on the treatment and prevention of mental health problems including anxiety, located at Macquarie University (*N*=7). A diagnosis of SoAD was made using the Anxiety and Related Disorders Interview Schedule for DSM-5 (ADIS-5; Brown & Barlow, 2014) for adult participants or the parent and child versions of the Anxiety Disorders Interview Schedule for Children for DSM-IV (ADIS-C/P; Silverman & Albano, 1996) for child participants. All interviews were conducted by trained clinicians, including co-author QW. Diagnoses were rated on a severity scale from 0 to 8, with a rating of 4 or higher indicating that the symptoms are causing significant life interference. Participants were included if SoAD was their principal diagnosis, and the presence of other anxiety and mood disorders was allowed (13% of the SoAD group met criteria for an additional anxiety disorder and 53% met criteria for a mood disorder). For the SoAD group, exclusionary criteria included a neurodevelopmental disorder, such as ASD, a co-morbid neurological condition/insult or intellectual disability. No participants met exclusionary criteria. Verbal ability standard scores using the Verbal Comprehension subtest from the WJ-III COG ranged from 93 to 120, (*M*=103.21; *SD*=8.16) and spatial ability standard scores using the Spatial Relations subtest from the WJ-III COG ranged from 88 to 116 (*M*=100.50; *SD*=8.99).

Mental age comparison group. Fifteen neurotypical children (8 male, 7 female) matched to the WS group on mental age were recruited though the Macquarie University Neuronauts Kids Science Club, a register of children and adolescents who elect to take part in research projects at Macquarie University. An average of mental age (MA) equivalency on the verbal and spatial tasks (see below for task descriptions) was used to match

neurotypical children to WS participants. Exclusionary criteria for the MA comparison group included: 1) prior neurological condition or insult; 2) a history of developmental delay; 3) intellectual disability (indexed by verbal or spatial ability scores ≤ 70); or 4) a clinical diagnosis (such as a psychological condition or sensory impairment). One male participant was subsequently excluded following a verbal ability standard score of 66 on the WJ-III COG. Verbal ability standard scores using the Verbal Comprehension subtest from the WJ-III COG for the remaining 14 participants ranged from 92 to 113, (*M*=103.71; *SD*=7.05) and spatial ability standard scores using the Spatial Relations subtest from the WJ-III COG ranged from 91 to 114 (*M*=100.93; *SD*=7.25).

Chronological age comparison group. Neurotypical participants (5 male, 10 female) matched to the clinical groups on chronological age (CA) were recruited through the Macquarie University Neuronauts Kids Science Club or through the Macquarie University undergraduate psychology participation pool, a register of University students who participate in research in return for course credit. The same exclusionary criteria were used as for the MA comparison group. No participants met exclusionary criteria. Verbal ability standard scores using the Verbal Comprehension subtest from the WJ-III COG ranged from 83 to 120, (*M*=99.93; *SD*=8.85) and spatial ability standard scores using the Spatial Relations subtest from the WJ-III COG ranged from 89 to 121 (*M*=101.67; *SD*=6.35).

Measures and Procedure

Woodcock-Johnson Tests of Cognitive Ability – 3rd Edition (WJ-III COG; Woodcock et al., 2001). The select subtests Verbal Comprehension and Spatial Relations from the WJ-III COG (Woodcock et al., 2001) were utilised to obtain estimates of verbal and non-verbal (spatial-perceptual) ability. Verbal Comprehension involves naming objects, providing synonyms and antonyms for a range of words, and completing verbal analogies. Spatial Relations requires participants to look at shapes and determine which

pieces (from a selection of five options) would, when oriented correctly, join together to create the completed shape. These subtests have been shown to reliably measure comprehension-knowledge (*Gc*) and visual-spatial thinking (*Gv*), with median reliabilities of 0.97 and 0.86, respectively (Woodcock et al., 2001).

Biographical learning task. The current study employed a biographical face learning paradigm, originally developed by Charmet-Mougey et al. (2012) for use in neurotypical adults. This paradigm has since been modified for use with neurotypical children and individuals with WS (Boulton & Porter, 2017). Images from 24 different actors (12 male, 12 female), displaying neutral expressions were displayed to participants. Images were selected from the NimStim standardised face set and all identities selected were reliably identified as expressing neutral expressions by independent raters (Tottenham et al., 2009). The 24 faces were divided into three blocks. A fictional biographical vignette was presented with each block of faces, describing the individuals as: (1) *trustworthy characters*, where the faces were described as belonging to individuals who were trustworthy or 'good'; (2) *neutral characters*, where the faces were described as belonging to individuals who were neutral or 'neither good nor bad' and (3) *untrustworthy characters*, where the faces were described as belonging to individuals who were untrustworthy or 'bad'. Each block comprised four male and four female faces. The character types corresponding to each block were counterbalanced across participants to control for biases in responding. Counterbalancing was also employed to control for differences in perceived trustworthiness between faces.

To facilitate learning, separate training and testing phases were conducted. During the training phase, each block of faces was presented with a colour tint. LunaPic online picture editing software (www.lunapic.com) was used to tint each block blue, purple or orange. These colours were selected as they were considered to be relatively neutral and unlikely to be implicitly associated with emotionally salient information (Sutton & Altarriba, 2016;

Takahashi & Kawabata, 2018). Colour tints were counterbalanced across conditions (blocks) and participants. Before each block of faces was presented, the corresponding biographical vignette (trustworthy characters, neutral characters, untrustworthy characters) was read aloud to the participant by the experimenter. Participants were instructed to look at each face until they believed they had memorised which character type it belonged to. Participants were able to look at the faces as many times as they liked and for as long as they liked. Once participants felt confident that they had memorised each face, the testing phase commenced. Each face was presented in greyscale and participants were asked to identify the character type of each face. Participants were provided with instant feedback after responding, and the dot-probe task was not completed until participants were able to correctly label the character type of each face (when presented in greyscale) at an accuracy level of at least 80 percent. Participants were able to go back and look at the training stimuli (faces grouped by vignette type with colour tints) as often as they liked in order to help them remember the character type for each face. Once an accuracy level of at least 80 percent had been established for all participants, the dot-probe task was conducted using the faces in greyscale.

Dot-probe task and data processing. Following the biographical learning task, participants completed a dot-probe task. The dot-probe task used in the current study was similar to that used in previous studies with WS individuals (Dodd & Porter, 2010). In each trial, participants were presented with a fixation cross (500ms), followed by the simultaneous presentation of a biographically neutral face stimulus and a biographically salient face stimulus (trustworthy or untrustworthy) presented on either side of the fixation cross (500ms), followed by the presentation of a visual probe in the same location as either the neutral or salient stimulus. The probe remained on the screen until a response had been made or until 10 seconds had passed. The inner edge of each image was 1.60 cm away from the fixation cross and each image was 13.44 cm (506 pixels) wide by 16.35 cm (618

pixels) high with a visual angle of 12.78°. The probe was presented 4.40 cm away from the fixation cross and was a black dot measuring 0.40 cm. Participants were seated approximated 60cm away from a Samsung 27" LED monitor and were provided with a custom button box, which had a centre button, a button on the left and a button on the right. Participants were instructed to press the button that corresponded to the side that the probe was on as quickly as possible. Participants' response to the probe, or the timeout of the probe was followed by a 100 tick (approximately 1672ms) intertrial interval. The dot-probe task included a total of 288 experimental trials divided into 12 blocks.

There were 16 critical trials incorporated in each block – eight in which a trustworthy character was presented side by side with a neutral character and eight in which an untrustworthy character was presented side by side with a neutral character. In addition to the critical trials, each block also included eight neutral trials, with two neutral characters being presented side by side to provide a baseline for participants' reaction time when the character manipulation was not presented. Character manipulation (trustworthy/untrustworthy), character position (left/right), and probe position (left/right) were ordered such that each block included four trustworthy-congruent trials, four trustworthy-incongruent trials, four untrustworthy-congruent trials, and four untrustworthy-incongruent trials. Trials were randomised within blocks for each participant. The position of the character manipulation and probe were counterbalanced within conditions, as was the position of the probe throughout the eight neutral trials. Six practice trials were completed at the start of the experiment and participants were given an opportunity to ask questions before the experimental trials began.

To examine attention bias to threat, data was processed as previously described (Dodd & Porter, 2010). Trials with timing errors (trials with reaction times [RTs] of <200ms or >3000ms) and incorrect trials were excluded, and a mean and standard deviation were calculated for each participant. Further, RTs more than two standard

deviations above each participants' mean were excluded. Trustworthy attention bias scores were calculated by subtracting the RTs for congruent trials from incongruent trials for trustworthy characters, and untrustworthy attention bias scores were calculated by subtracting the RTs for congruent trials from incongruent trials for untrustworthy characters. A positive score indicates a faster RT for congruent trials, suggesting an attentional bias towards those characters, while a negative score indicates a faster RT for incongruent trials, suggesting an attentional bias away from those characters.

In an effort to address some of the dispute surrounding the utility and interpretability of the dot-probe task (Waechter et al., 2013), a secondary outcome measure, attention bias variability was calculated (Price et al., 2015). Unlike attention bias scores, where a single bias score is computed based on all trials in a session, attention bias variability is an index of individual attention fluctuation throughout a session. This has been described as a potentially more reliable index of attention bias, as it is an explicit index of within-individual, intrasession variation (Price et al., 2015). Further, when comparing attention bias variability to overall attention bias scores in samples of clinical and nonclinical adults, as well as paediatric samples, Price and colleagues reported that attention bias variability displayed superior stability across samples. To investigate group differences in attention bias variability, we analysed dot-probe task data using a moving average algorithm, as described in Schneier et al. (2016).

Dot-probe trials were separated into: neutral trials; trustworthy-congruent trials; trustworthy-incongruent trials; untrustworthy-congruent trials and untrustworthy incongruent trials. A moving average algorithm then calculated mean RTs for all sequential trial blocks (10 trials per block) and a series of successive attention bias scores (incongruent minus congruent trials) were calculated for each block. This was done separately for blocks containing trustworthy and untrustworthy trials. We then calculated the standard deviation of these successive bias scores to obtain a measure of variation in

trustworthy and untrustworthy attention bias across the session as a whole. This was then divided by the participant's mean RT across the session to control for any variance in RTs. The resulting attention bias variability index reflects the within-subject, within-session variability of the attention bias, normalised to individual task performance, rather than measuring the attention bias itself. Within an individual, a larger attention bias variability for trustworthy characters indicates greater fluctuations in attention towards and/or away from trustworthy characters. Likewise, a larger attention bias variability for untrustworthy characters indicates greater fluctuations in attention towards and/or away from untrustworthy characters.

To explore overall RT variability, we also calculated the intra-individual coefficient of variation for neutral trials, trustworthy trials and untrustworthy trials. This index was calculated by dividing the standard deviation for neutral, trustworthy and untrustworthy trials by the mean RT for these trials. This index provides a measure of RT variability for each character type, as opposed to measuring bias variability for trustworthy and untrustworthy characters.

Statistical analysis

SPSS version 24 (IBM) was used to conduct all statistical analyses. One-way analyses of variance (ANOVAs) were used to explore group differences on continuous variables (e.g. CA and MA). Fisher's exact test was used to explore group differences on categorical variables (i.e., sex). ANOVAs were used to explore between- and within-group differences on overall attention bias and attention bias variability indices. With regards to follow-up analyses, we made an a priori decision to only compare the MA-matched control group to the WS group, given that the rationale for including the former group was to compare WS participants to MA-matched peers. For instances where increased attention bias variability was observed in the absence of an overall attention bias, Pearson's correlations were used to explore the relationship between attention bias variability and

overall RT variability (intra-individual coefficient of variation). As a result of the small sample size, and in an effort to minimise the likelihood of a Type-II error, corrections for multiple comparisons were not applied and alpha was set to 0.05 for all following analyses (see Rothman, 1990). For any critical values at or approaching an alpha level of 0.05, moderate to large effect sizes would minimise the likelihood of a Type-I error. As such, and to aid in the interpretation of analyses, effect sizes are reported throughout the results (for *d*: 0.2 = small effect size, 0.5 = medium effect size, 0.8 = large effect size; for *r*: 0.1 = small effect size, 0.3 = medium effect size, 0.5 = large effect size according to Cohen, 1988).

Results

Two participants (1 ASD, 1 WS), were unable to complete the dot-probe task, one due to poor compliance and the other due to only pressing the left button on the button box. Thus, the final sample included 72 participants (15 CA, 14 MA, 15 SoAD, 14 ASD, 14 WS) who completed the dot-probe task with analysable data. The original sample and the final sample did not differ on chronological age, mental age, verbal ability, or spatial ability, (all *p*-values >.31).

As can be seen in Table 1, there were no significant differences in chronological age between the WS, ASD, SAD and CA control groups, nor was there a significant difference in mental age between the WS and MA control groups. The groups were found to differ on sex due to the SAD group being predominantly comprised of females. A recent review reports higher prevalence rates of SoAD, as well as elevated clinical severity of the disorder in women (Asher, Asnaani, & Aderka, 2017), which may explain the increased proportion of females in this sample. Excluding the SAD participants, there were no significant group differences in sex (p=.642).

Group differences in verbal ability were observed; standard scores in the ASD, SoAD, CA- and MA-matched control groups were significantly higher than those in the

WS group (all *p*-values <.001). Similarly, group differences in spatial ability were observed; standard scores in the ASD group were significantly higher than those in the SoAD and CA-matched control groups (all *p*-values <.004) while standard scores in the ASD, SoAD, CA-matched and MA-matched control groups were significantly higher than those in the WS group (all *p*-values <.001). Given the group differences in verbal and spatial ability, we assessed whether these variables were related to either attention bias scores or attention bias variability. Verbal ability correlated with trustworthy attention bias in the WS (*r*=–.667, *p*=.009) group and with untrustworthy bias in the SoAD (*r*=–.546, *p*=.044) group only. Spatial ability was not related to attention bias scores or attention bias variability within any group (all *p*-values >.09). Whilst a standard approach in instances of between-group differences in cognitive ability is to control for cognitive ability statistically, this can increase Type-II error. Additionally, the suitability of including cognitive ability as a covariate when the relationship between cognitive ability and the dependent variable(s) of interest differs across groups has been brought into question (for a broader discussion see Dennis et al., 2009 and Miller & Chapman, 2001). Given that much of the literature covarys for cognitive ability in instances such as ours (although, see Jarivinen, Ng & Bellugi, 2015 and Jarvinen et al., 2015 for recent exceptions), we conducted all analyses with and without verbal and spatial ability included as covariates and found that the pattern of results did not differ. Thus, we report the results of the simple models without covariates. This methodology aligns with that recently employed by Chevallier et al. (2015) in ASD individuals.

Table 1

Demographic characteristics for each group

	CA	ASD	SoAD	WS	MA	$p^{a,b,c}$
	n=15	*n*=14	*n*=15	*n*=14	*n*=14	
Chronological Age	21.29 (6.99)	26.98 (8.48)	23.01 (7.58)	21.07 (7.78)	8.88 (1.54)	0.16
Mental Age	–	–	–	8.14 (1.79)	8.63 (1.70)	0.46
Sex (n, % Female)	10 (67%)	6 (43%)	14 (93%)	7 (50%)	7 (47%)	0.03

Note: $^{a,b,c}p$-value for ANOVA (chronological age), independent samples *t*-test (mental age) and Fisher's exact test (sex) for any group differences. Data expressed as mean (SD). Chronological age and Mental age are reported in years. CA=Chronological age-matched controls; ASD=Autism Spectrum Disorder; SoAD=Social Anxiety Disorder; WS=Williams syndrome; MA=mental age-matched controls.

Dot-Probe Task

To explore group differences in performance on the dot-probe task, analyses were conducted separately for attention bias scores and attention bias variability. The percentage of trials excluded were: 4.12% (ASD group), 5.58% (SoAD group), 6.27% (CA-matched controls), 7.12% (WS group), and 11.53% (MA-matched controls). The percentage of trials excluded in the ASD, SoAD, CA-matched control and WS groups was significantly lower than that in the MA-matched control group (all *p*-values<.05). Further, the percentage of trials excluded in the ASD group was significantly lower than that in the WS group, (*p*=.007) and the SoAD group, (*p*=.050). The mean RTs by condition for each group are displayed in Table 2.

Table 2

Reaction time (ms) for each group by condition on the dot-probe task

Condition	CA	ASD	SoAD	WS	MA
	(*n*=15)	(*n*=14)	(*n*=15)	(*n*=14)	(*n*=14)
All trials	356 (57)	322 (34)	336 (44)	501 (121)	487 (82)
Trustworthy-Congruent	356 (60)	322 (35)	335 (46)	496 (125)	485 (81)
Trustworthy-Incongruent	353 (55)	321 (33)	337 (48)	508 (130)	482 (80)
Untrustworthy-Congruent	355 (61)	321 (34)	333 (41)	500 (119)	488 (87)
Untrustworthy-Incongruent	358 (56)	322 (35)	338 (42)	499 (120)	486 (79)
Neutral-Neutral	359 (57)	322 (35)	336 (44)	503 (114)	492 (85)

Note: Data expressed as mean (SD). CA=Chronological age-matched controls; ASD=Autism Spectrum Disorder; SoAD=Social Anxiety Disorder; WS=Williams syndrome; MA=mental age-matched controls.

Attention bias scores. Univariate ANOVAs were conducted to compare groups on mean bias scores[1]. Due to a significant group difference in overall RT, $F(4,67)=19.47$, $p<.001$, partial $\eta^2=.54$, mean RT for all trials was entered into analyses as a covariate. This group difference was due to the WS group having significantly slower RTs than the CA-matched control, ASD and SoAD groups (all *p*-values <.001). The mean attention bias scores for trustworthy and untrustworthy characters for all groups are displayed in Table 3.

Trustworthy bias. A comparison of the WS, ASD, SoAD, CA and MA participants revealed a significant difference in mean attention bias towards trustworthy characters between the five groups, $F(4,66)=2.71$, $p=.038$, partial $\eta^2=.14$. Post-hoc pairwise comparisons indicated that this difference resulted from a significantly larger bias toward trustworthy characters among individuals with WS, relative to: individuals with ASD;

[1] All reported analyses were repeated with bootstrapping given some evidence of non-normal distribution of variables, as follows. Within the CA group, trustworthy attention bias scores were non-normally distributed, with skewness of -1.093 (*SE*=0.580) and kurtosis of 3.178 (*SE*=1.121). Within the ASD group, untrustworthy attention bias variability indices were non-normally distributed, with skewness of 1.411 (*SE*=0.597) and kurtosis of 3.640 (*SE*=1.154). Within the WS group, trustworthy attention bias scores were non-normally distributed, with skewness of -1.277 (*SE*=0.597) and kurtosis of 1.974 (*SE*=1.154). Given that there were no differences in the pattern of results when bootstrapping was applied, results from the original analyses are reported.

t(15.17)=-3.29, *p*=.005, *d*=1.42; individuals with SoAD, *t*(27)=-2.32, *p*=.028, *d*=0.88; CA-matched controls, *t*(27)=-2.86, *p*=.008, *d*=1.06; and MA-matched controls, *t*(26)=-2.36, *p*=.026, *d*=.91. One sample *t*-tests revealed that the trustworthy bias in the WS group differed significantly from zero, *t*(13)=3.25, *p*=.006, *d*=0.87, meaning WS individuals were showing an attention bias towards trustworthy characters, as indexed by faster RTs on trustworthy congruent (vs. incongruent) trials. This was not the case for the CA, MA, ASD or SoAD groups, where trustworthy bias scores did not differ significantly from zero (all *p*-values >.37).

Untrustworthy bias. A comparison of the WS, ASD, SoAD, CA and MA participants revealed no significant difference in mean attention bias towards untrustworthy characters between the five groups, *F*(4,66)=.29, *p*=.882, partial η^2=.02. One sample *t*-tests revealed that the untrustworthy bias in the SoAD group differed significantly from zero, *t*(14)=4.16, *p*=.001, *d*=1.07, meaning SoAD individuals were showing an attention bias towards untrustworthy characters, as indexed by faster RTs on untrustworthy congruent (vs. incongruent) trials. No such difference was found for the CA, MA, ASD or WS groups, where untrustworthy bias scores did not differ significantly from zero (all *p*-values >.45).

Table 3

Trustworthy and Untrustworthy bias scores for each group on the dot-probe task

	CA	ASD	SoAD	WS	MA
	(*n*=15)	(*n*=14)	(*n*=15)	(*n*=14)	(*n*=14)
Trustworthy bias	-2.56 (13.46)	-0.65 (3.98)	2.08 (8.63)	**11.88 (13.70)**[a]	-3.00 (19.13)
Untrustworthy bias	3.53 (17.70)	0.23 (8.55)	5.02 (4.67) [a]	-1.26 (16.14)	-2.16 (18.83)

Note: Data expressed as mean (SD). CA=Chronological age-matched controls; ASD=Autism Spectrum Disorder; SoAD=Social Anxiety Disorder; WS=Williams syndrome; MA=mental age-matched controls. **Bold**=significant bias between groups (p <.05). [a] indicates that attention bias was significantly different from zero (p <.01).

Attention bias variability. To assess differences between groups in attention bias variability for trustworthy and untrustworthy characters, one-way ANOVAs were conducted. In line with Schneier et al. (2016), pre-planned pairwise contrasts compared each clinical group with CA-matched controls, as well as comparing the WS group to MA-matched controls. Clinical groups were also compared to each other. The average attention bias variability for trustworthy and untrustworthy characters for all groups is shown in Table 4.

Table 4

Attention bias variability for each group on the dot-probe task

	CA	ASD	SoAD	WS	MA
	(*n*=15)	(*n*=14)	(*n*=15)	(*n*=14)	(*n*=14)
Trustworthy ABV	0.06 (0.02)	0.04 (0.01)	0.05 (0.02)	0.07 (0.02)	0.08 (0.03)
Untrustworthy ABV	0.05 (0.03)	0.04 (0.02)	0.05 (0.01)	0.07 (0.03)	0.07 (0.02)

Note: Data expressed as mean (SD). CA=Chronological age-matched controls; ASD=Autism Spectrum Disorder; SoAD=Social Anxiety Disorder; WS=Williams syndrome; MA=mental age-matched controls; ABV=attention bias variability.

When looking at attention bias variability for trustworthy characters, a statistically significant difference was observed between the ASD group and the CA-matched control group, $t(68)=2.32$, $p=.023$, $d=1.11$. As seen in Figure 2a, compared to CA-matched controls, ASD individuals displayed significantly less fluctuation in their attention bias for trustworthy characters throughout the dot-probe task, with only minor fluctuations below zero (no bias towards or away from trustworthy characters) across the dot-probe task. Further, statistically significant differences were observed between the WS, ASD and SoAD groups, with WS individuals displaying significantly more fluctuation in their attention bias for trustworthy characters compared to both ASD, $t(68)=3.69$, $p<.001$, $d=1.37$, and SoAD, $t(68)=3.16$, $p=.002$; $d=1.32$, individuals. These differences are illustrated in Figure 2g. No other pairwise contrasts reached statistical significance (all *p*-values >.084).

When looking at attention bias variability for untrustworthy characters, a statistically significant difference was observed between the WS group and the CA-matched control group, $t(68)=-2.60$, $p=.011$, $d=.94$. As illustrated in Figure 2f, compared to CA-matched controls, WS individuals displayed significantly more fluctuation in their attention bias for untrustworthy characters throughout the dot-probe task, with relatively large fluctuations below zero (increased bias away from untrustworthy characters) across the dot-probe task. A similar pattern was observed when WS individuals were compared to both individuals with ASD, $t(68)=3.93$, $p<.001$, $d=1.44$, and SoAD, $t(68)=2.71$, $p=.009$, $d=1.02$, with WS individuals displaying significantly larger fluctuations in their attention bias away from untrustworthy characters compared to both groups (see Figure 2g and 2h). No other pairwise contrasts reached statistical significance (all p-values >.17). Average attention bias variability for trustworthy and untrustworthy characters in each group across the dot-probe task is shown in Figure 2.

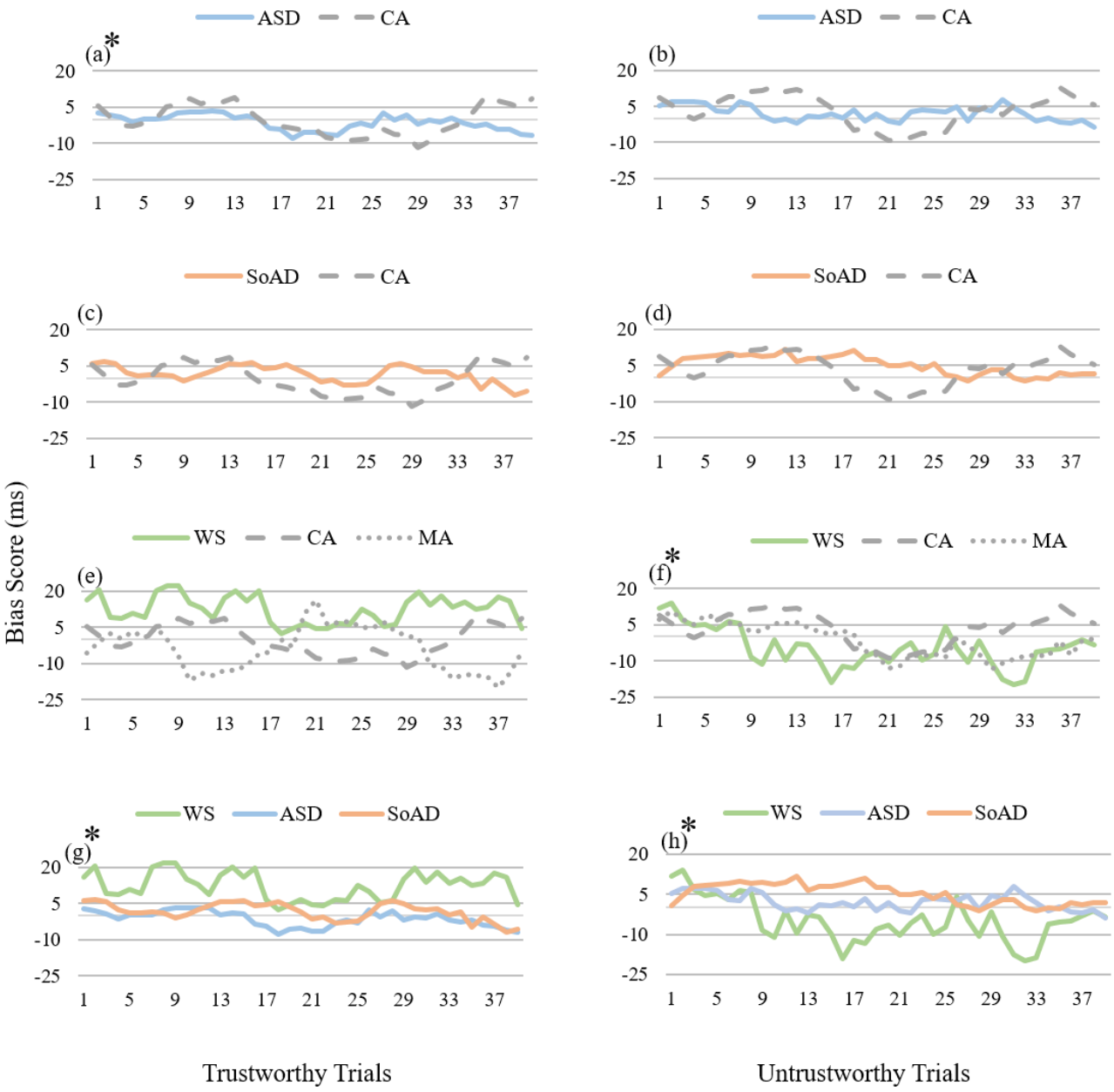

Figure 2. Average attention bias variability by group across trustworthy and untrustworthy trials. Bias scores greater than zero indicate fluctuations in attention towards trustworthy or untrustworthy characters, while bias scores less than zero indicate fluctuations in attention away from trustworthy or untrustworthy characters. * indicates $p<0.05$.

As others have suggested that increased attention bias variability in the absence of an overall attention bias may reflect more general attention deficits (Swick & Ashley, 2017), we examined the relationship between attention bias variability for untrustworthy characters and our measure of overall RT variability, the intra-individual coefficient of variation, for untrustworthy trials in the WS group, where increased attention bias variability was observed in the absence of an overall attention bias for untrustworthy characters[2]. As anticipated, there was a strong positive correlation between these measures of variability (r=.75; p=.002). The average intra-individual coefficient of variation for neutral, trustworthy and untrustworthy trials in each group across the dot-probe task is shown in Table 5. As increased attention bias variability in the absence of an overall attention bias was observed only in the WS group and only for untrustworthy characters, no additional relationships between attention bias variability and overall RT variability were explored.

Table 5

Intra-individual coefficient of variation for each group on the dot-probe task

	CA	ASD	SoAD	WS	MA
	(n=15)	(n=14)	(n=15)	(n=14)	(n=14)
ICV – neutral trials	0.15 (0.02)	0.13 (0.02)	0.14 (0.03)	0.23 (0.06)	0.18 (0.04)
ICV – trustworthy trials	0.15 (0.03)	0.12 (0.02)	0.14 (0.02)	0.23 (0.06)	0.18 (0.04)
ICV – untrustworthy trials	0.16 (0.03)	0.12 (0.02)	0.13 (0.02)	0.24 (0.06)	0.18 (0.03)

Note: Data expressed as mean (SD). CA=Chronological age-matched controls; ASD=Autism Spectrum Disorder; SoAD=Social Anxiety Disorder; WS=Williams syndrome; MA=mental age-matched controls; ICV=Intra-individual coefficient of variation.

[2] While increased attention bias variability for trustworthy characters was also observed in the WS group, relative to the ASD and SoAD groups, this variability occurred in the presence of an overall attention bias for trustworthy characters, suggesting that this finding likely reflects bias variability rather than general attention deficits.

Discussion

There is evidence that individuals with WS, ASD and SoAD display abnormalities in attention for faces (Bantin et al., 2016; Plesa Skwerer, 2017). However, no research to date has directly compared attention for faces across these populations. The current study utilised a cross-disorder comparison to investigate attention for faces in WS, ASD and SoAD. Further, we considered whether atypical attention for faces in people with WS, ASD and SoAD is modulated by biographical information. Results were largely consistent with our hypothesised pattern of: i) increased attention for trustworthy characters in WS; ii) a lack of attention for either trustworthy or untrustworthy characters in ASD; and iii) increased attention for untrustworthy characters in SoAD.

Firstly, in line with our predictions, we observed an attention bias for trustworthy characters in WS individuals that was significantly larger than that seen in both ASD and SoAD individuals, as well as both CA- and MA-matched controls. This finding is consistent with prior reports of a bias for positive, or happy, faces in WS that is observed across multiple studies and modalities. For instance, an attention bias for happy faces has been reported in this group using similar dot-probe paradigms (Dodd & Porter, 2010; Goldman et al., 2016). Further, WS individuals display increased physiological arousal to happy faces (Jarvinen, Ng, Crivelli, Arnold, et al., 2015) as well as elevated amygdala reactivity when viewing happy faces (Haas et al., 2009), suggesting that there may be a biological basis to the bias for positive faces in WS. The increased attention bias for trustworthy characters observed in WS individuals in the current study suggests that this bias for positive faces may extend beyond emotional expressions to faces that have been paired with positive biographical information. Moreover, these findings align with the hypersociability and desire for social interaction seen in this group (Thurman & Fisher, 2015).

The attention bias for untrustworthy characters observed in SoAD individuals did

not differ significantly from that seen in WS individuals or CA-matched controls. Whilst unexpected, previous studies have failed to observe an attention bias for threatening faces in SoAD (Schneier et al., 2016), likely due to the clinical heterogeneity of the disorder and the small effect sizes often reported (Bantin et al., 2016). However, we found evidence for a within-group attention bias for untrustworthy characters in this group, with SoAD individuals exhibiting a tendency to direct their attention toward untrustworthy characters. This result aligns with both prior reports of an increased overall attention bias for threatening faces in SoAD (Bantin et al., 2016) and more broadly with increased attention towards threat in the environment, which is believed to maintain and exacerbate the social avoidance seen in SoAD (Wong & Rapee, 2016).

As anticipated, no between- or within-group differences for attention bias were observed in the ASD group. This lack of attention for faces paired with salient biographical information is consistent with prior findings of decreased attention towards social stimuli in ASD (Chita-Tegmark, 2016) and corresponds to the hyposociability and decreased social interest often seen in this disorder (Chevallier et al., 2012).

Interestingly, we observed decreased attention bias variability for trustworthy characters in the ASD group, relative to CA-matched controls. Given that attention bias variability has not yet been investigated in ASD, this finding is somewhat difficult to interpret, however it may represent an attentional marker for the lack of interest in faces seen in ASD. On the whole, eye-tracking studies suggest that ASD individuals display reduced social attention relative to neurotypical controls, spending less time attending to social stimuli (M. Chita-Tegmark, 2016). It is possible that the decreased attention bias variability for trustworthy characters seen in the ASD group reflects a lack of attention either towards or away from these stimuli. This atypicality in attention allocation aligns with recent functional neuroimaging research, where ASD individuals exhibited hyporeactivity in response to faces in certain brain regions, such as the fusiform face area

and amygdala, relative to neurotypical controls (Whyte, Behrmann, Minshew, Garcia, & Scherf, 2016).

Compared to both ASD and SoAD individuals, WS individuals displayed increased attention bias variability for trustworthy characters. Coupled with the overall attention bias for trustworthy characters observed in the WS group, this finding may represent an attentional marker for the heightened interest in positive faces seen in WS (Goldman et al., 2016; Haas et al., 2009). Indeed, results suggest that WS individuals displayed larger fluctuations in their attention *towards* trustworthy characters across the dot-probe task compared to both ASD and SoAD individuals, however, not compared to CA-matched controls, suggesting that these findings were not solely attributable to increased variability in general attention within WS individuals during the dot-probe task. Whilst speculative, it is possible that this finding reflects the atypical attention for faces reported across these groups, that is, increased attention for faces in WS individuals, alongside attenuated attention for faces in ASD and SoAD individuals.

We also observed increased attention bias variability for untrustworthy characters in WS individuals compared to ASD and SoAD individuals, as well as CA-matched controls. However, this was strongly correlated with overall reaction time variability on untrustworthy trials. Following from the recommendations of Swick and Ashley (2017), we acknowledge that the increased attention bias variability for untrustworthy characters may reflect more general impairments in attention for untrustworthy characters in the WS group, given the lack of overall attention bias for untrustworthy characters. Attention and executive function deficits are common in WS and have been hypothesised to contribute to abnormal social approach behaviours and social functioning impairments (Little et al., 2013; Ng-Cordell, Hanley, Kelly, & Riby, 2018), so it is possible that attentional impairments may have been present during the dot-probe task, resulting in a less consistent performance in WS individuals relative to the ASD, SoAD and CA-matched control

groups. However, relative to the ASD and SoAD groups, the increased attention bias variability *away* from untrustworthy characters seen in the WS group was coupled with an increased attention bias variability *towards* trustworthy characters, as well as an overall attention bias for trustworthy characters. If WS individuals are preferentially attending to positive faces and, conversely, showing impairments in attention when attending to threatening faces, this may correspond to a 'positive bias' in everyday life, where positive social stimuli are prioritised, and impairments in processing threatening stimuli occur.

It is possible that our attention bias variability findings may have been affected by the biographical face stimuli utilised in this study. Given that the biographical face stimuli were perceptually neutral, the top-down control processes influencing attention for these faces may possibly be more absolute in the sense that execution of these processes leaves little room for variability. This might contrast to bottom-up processes that influence attention that may lead to more variability in attention and may be more activated when emotional expressions (rather than biographical faces) are used in the dot-probe paradigm. Keeping in mind the limitations of attention bias variability outlined above, further exploration of the attention bias variability index in response to emotional faces in WS, ASD and SoAD, potentially using existing dot-probe data as recommended by Price et al. (2015), is warranted.

Using perceptually neutral faces, we manipulated biographical information to investigate attention for positive (trustworthy) and threatening (untrustworthy) biographical faces in WS, ASD and SoAD. Our results correspond to previous findings in these disorders when attention for faces is investigated by manipulating emotional expression (e.g. see Bantin et al. (2016); Goldman et al. (2016); May et al. (2015)). That is, we found evidence for an increased attention bias for trustworthy characters in WS individuals, no clear attention bias for trustworthy or untrustworthy characters in ASD individuals, and an increased attention bias for untrustworthy characters in SoAD. In

addition, these results appear consistent with previous findings of amygdala hyperactivity for positive faces in WS (Haas et al., 2009); hypoactivity for emotional faces (regardless of expression) in ASD (Aoki et al., 2015); and hyperactivity for threatening faces in SoAD (Binelli et al., 2014). It is possible that the disorder-specific attentional biases (or lack thereof in the case of ASD) for faces of varying valence reported throughout the literature represent an attentional marker for amygdala dysfunction in WS, ASD and SoAD individuals. Future neuroimaging studies may benefit from cross-disorder comparisons, allowing authors to directly compare and contrast amygdala dysfunction in disorders characterised by disparate social profiles.

As the biographical stimuli utilised in this study appear to elicit largely similar attentional responses to those seen when social-perceptual stimuli are used in WS, ASD and SoAD individuals, an investigation of amygdala reactivity to these stimuli would be of particular interest in these populations. Previous research in neurotypical adults has found that perceptually neutral face stimuli paired with salient biographical information elicit amygdala reactivity that is congruent with the type of information provided – for example, hyperactivity for malevolent biographical information (Charmet-Mougey et al., 2012). Such findings suggest that the amygdala may play a role in more complex top-down processing of emotional information, in addition to bottom-up sensory-based processing of emotional expressions. Given that amygdala dysfunction has been hypothesised as a key neurobiological feature of WS, ASD and SoAD and is believed to contribute to the distinctive social profile seen in each disorder, an investigation of amygdala reactivity to positive and threatening biographical stimuli would help inform our understanding of the role of this brain region in the top-down processing of emotional information across these disorders.

Practical implications

Given that the testing phase of the biographical face task required participants to

correctly label the character type of each face at an accuracy level of at least 80 percent, these results indicate that people with WS, ASD and SoAD can learn salient biographical information about perceptually neutral faces. Future interventions may benefit from adapting the biographical task used here to encourage these individuals, at least in familiar scenarios, to think about person-based characteristics and use this information to inform decisions about social interactions. Such an intervention could be used to help WS individuals understand when to engage in social interactions and likewise when to avoid social interactions. For example, if WS individuals were encouraged to consider biographical, or person-based, characteristics of a familiar person prior to approaching them, they may appropriately hesitate before approaching people who are less desirable. Similarly, they may choose to avoid a person they associate with negative characteristics, such as someone who has previously wronged them (e.g., a bully at school or in the workplace). Indeed, in our research with WS individuals, anecdotally we find that WS individuals are reported to approach and engage in interactions with people who have 'done them wrong' in the past, suggesting that such an intervention would be advantageous for this group.

In a conceptually related, yet distinct vein, an intervention of this nature has potential in ASD and SoAD. In general, people with ASD display social avoidance that is believed to be driven by a lack of interest in social situations, while those with SoAD display social avoidance resulting from a fear of negative evaluation. If an intervention were developed that encouraged individuals to think about the biographical, or personal, characteristics of a familiar person before making a social interaction decision, this may increase social interaction with known others (for example, acquaintances) in ASD, and may minimise the default response of social avoidance seen in SoAD.

Methodological considerations and future directions

A methodological strength of the current study was the use of a cross-disorder

comparison. When investigating disorders with contrasting overt social profiles, cross-disorder comparisons can help to highlight the syndrome-specific and syndrome-shared features of disorders in a way that is difficult when exploring a syndrome in isolation. The present findings suggest that attention for faces is likely a syndrome-specific feature of these disorders, with quantitative differences observed between WS, ASD and SoAD individuals. Building on the evidence that highlights abnormalities in attention for faces in these populations when compared to neurotypical controls alone, the current results suggest that individuals with WS, ASD and SoAD also display marked differences in their attention for faces when compared to each other. Future research would benefit from the use of additional cross-disorder comparisons in order to further elucidate differences in social behaviour across neurodevelopmental and anxiety disorders. Such research would deepen our understanding of social behaviour and inform the development of targeted interventions for use in disorders where social dysfunction contributes to poor social and mental health outcomes.

The current findings should be considered in the context of certain methodological considerations. Despite the small sample size, large effect sizes were observed (Cohen, 1988), highlighting the clinical significance of these findings. Further, to the best of our knowledge, this was the first study to conduct a cross-disorder comparison of WS, ASD and SoAD. These results suggest that attention for faces differs across these populations and is modulated by biographical information. Given the prior concerns raised with respect to the dot-probe task (e.g. see Price et al. (2015); Waechter et al. (2013)), we attempted to address the limitations surrounding the use of an overall attention bias score, as well as the use of attention bias variability alone. Our results indicate that both outcome measures – overall attention bias index and attention bias variability – provide valuable information about attention for faces across disorders and further elucidate how attention for faces differs between disorders characterised by different social features. Future research would

benefit from employing the biographical stimuli used in this study across a number of methodologies such as eye-tracking and functional neuroimaging, to better pinpoint where abnormalities occur and how they contribute to the similar functional social impairments seen across WS, ASD and SoAD.

Conclusion

The current research provides evidence to suggest that the differing overt social features seen in WS, ASD and SoAD are also observable at the attentional level. While prior studies have reported similar results using social-perceptual stimuli and looking at each disorder in isolation, our study is the first to conduct a cross-disorder comparison of attention for faces using biographical stimuli in these disorders. Critical areas of interest for future research include the use of additional methodologies such as eye-tracking and functional neuroimaging to further explore how biographical face stimuli are processed in people with these conditions. Shedding light on the differences in social attention between WS, ASD and SoAD individuals will help to reveal subtle group differences in social processing that may not be revealed by comparing a single condition to a neurotypical control group. Such differences can then inform both our existing theories of social dysfunction, as well as disorder-specific interventions.

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Paper 3

Emotion Recognition in Williams syndrome, Autism Spectrum Disorder and Social Anxiety Disorder: The Influence of Biographical Information

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Abstract

Williams syndrome (WS), Autism Spectrum Disorder (ASD) and Social Anxiety Disorder (SoAD) are conditions which present with divergent social profiles, as well as abnormalities in social processing. Abnormalities in social processing across these conditions may be related to emotion recognition deficits and interpretation biases. Using a cross-disorder comparison, the current study investigated whether manipulating the biographical information associated with a face influenced: (1) emotion recognition abilities and (2) the type of emotion misclassifications made between groups. Biographical information did not influence either emotion recognition abilities or misclassifications in any groups. However, relative to neurotypical controls and SoAD individuals, a subset of WS individuals more frequently misclassified neutral expressions as happy, suggestive of a positive interpretation bias in certain individuals with this condition. These findings suggest that salient biographical information does not appear to influence the direct perception of emotional expressions in WS, ASD or SoAD individuals. However, findings reveal subtle differences in emotion misclassifications between WS, ASD and SoAD individuals which may help to further elucidate abnormalities in social processing within each condition.

Emotion Recognition in Williams syndrome, Autism Spectrum Disorder and Social Anxiety Disorder: The Influence of Biographical Information

Introduction

The ability to accurately recognise and respond to social cues, such as facial emotional expressions, is crucial for successful social communication. For individuals with neurodevelopmental or anxiety disorders, this ability can be compromised, contributing to social dysfunction. For instance, in Williams syndrome (WS), difficulties identifying neutral and negative emotional expressions are observed (Jarvinen, Ng, Crivelli, Neumann, et al., 2015; Plesa Skwerer, Faja, et al., 2006). In Autism Spectrum Disorder (ASD), individuals show some impairments when recognising negative expressions, alongside a tendency to interpret neutral expressions as negative (Eack et al., 2015; Uljarevic & Hamilton, 2013). On the other hand, in Social Anxiety Disorder (SoAD), recognition of emotional expressions appears to be relatively intact, however, neutral or ambiguous expressions are often misinterpreted as negative by individuals with the condition (Bell et al., 2011; Peschard & Philippot, 2017). Despite some similarities and some differences in emotion recognition both within and across these three conditions, social isolation, diminished interpersonal relationships and poor mental health outcomes are commonly seen across all individuals (Jawaid et al., 2012; Ruscio et al., 2008).

For individuals with WS, a neurodevelopmental disorder caused by a microdeletion on chromosome 7 at 7q11.23 (Ewart, 1993), other people, and more specifically, faces, are particularly salient (Frigerio et al., 2006), and from infancy WS individuals spend increased time looking at the face (Mervis et al., 2003). Across development, in addition to the gregarious personality and elevated social approach tendencies considered characteristic of the disorder (Thurman & Fisher, 2015), individuals with WS continue to show this exceptional interest in faces (Mervis & Klein-Tasman, 2000), alongside specific competencies in recognising facial identities (Bellugi, 2000). Despite this strength in facial

recognition ability, a considerable body of literature suggests that WS individuals display deficits in emotion recognition ability relative to neurotypical controls (Gagliardi et al., 2003; Plesa Skwerer, Faja, et al., 2006; Plesa Skwerer, Verbalis, et al., 2006). Notably, there is also evidence of striking within-syndrome variability in emotion recognition capabilities (Porter et al., 2010).

For the most part, emotion recognition abilities in WS individuals seem to be poorer than would be expected based on their chronological age and deficits appear to be specific to negative emotions. Employing an emotion recognition task with basic emotional expressions (happy, anger, disgust, fear, sadness), earlier findings from Gagliardi and colleagues suggested that emotion recognition ability, particularly for negative faces, in WS individuals was poorer than that seen in neurotypical controls matched on chronological age, but commensurate with neurotypical controls matched on mental age (Gagliardi et al., 2003). These findings were supported by Plesa Skwerer and colleagues, where WS individuals performed similarly to individuals with non-specific learning/intellectual disabilities, and more poorly than their same aged neurotypical peers, when identifying a range of emotional expressions (Plesa Skwerer, Faja, et al., 2006; Plesa Skwerer, Verbalis, et al., 2006). This pattern of findings has since been reported using face stimuli varying in intensity (Little et al., 2013; Porter et al., 2007; Porter et al., 2010). Of note, certain emotions appear to be more easily recognised by WS individuals, as is the case in neurotypical individuals. Specifically, happy expressions are recognised most accurately by this group (Little et al., 2013; Plesa Skwerer, Faja, et al., 2006), aligning with the literature suggesting that intact recognition of this expression occurs early in development (Durand, Gallay, Seigneuric, Robichon, & Baudouin, 2007). Indeed, it is possible that impairments in emotion recognition, in combination with other atypicalities in face processing, such as increased attention for positive faces (Goldman et al., 2016) and a positive social bias (Godbee & Porter, 2013), could contribute to the striking social profile

seen in WS.

While increased social salience and hypersociability are considered key characteristics of the WS social profile, in contrast, social withdrawal and social interaction difficulties are core aspects of social behaviour in ASD. Individuals with ASD show a decreased interest in other people, which is thought to arise from diminished social motivation (Chevallier et al., 2012). The striking social differences between WS and ASD have attracted the interest of numerous researchers, with cross-disorder comparisons of face processing (e.g., see Riby & Hancock, 2009; Riby & Hancock, 2009a) , emotion recognition (Jarvinen et al., 2015; Lacroix, Guidetti, Roge, & Reilly, 2009; Riby, Doherty-Sneddon, & Bruce, 2008) , and everyday social functioning (e.g. see Lough et al., 2015) conducted over recent years.

When considering direct comparisons of emotion recognition abilities between WS and ASD, mixed findings emerge. While earlier research from Riby and colleagues (2008) suggested that WS individuals outperformed ASD individuals matched on nonverbal ability when identifying emotional expressions, Lacroix and colleagues (2009) reported the opposite pattern, with WS individuals showing emotion recognition impairments relative to ASD individuals matched on verbal mental age, with specific deficits for negative emotions such as sadness and fear. More recently, findings from Jarvinen et al. (2015) suggest that differences in emotion recognition ability may be emotion-specific, with WS individuals performing similarly to chronological-aged matched ASD individuals and neurotypical controls when identifying happy and fearful expressions, but showing a specific impairment when identifying neutral expressions, relative to both comparison groups. Such differences across studies may be reflective of variability in the intensity of the face stimuli used, heterogeneity across (or within) samples, methodological differences or a combination thereof. Indeed, the literature concerning emotion recognition in ASD alone has reported similarly dissonant results (e.g., see Uljarevic and Hamilton, 2013 for a

meta-analysis).

A substantial body of research has investigated emotion recognition abilities in ASD, with mixed results. Where some studies report poorer performance in ASD individuals relative to neurotypical controls across emotional expressions, others suggest that this ability is largely commensurate with neurotypical individuals (for a review, see Harms, Martin, & Wallace, 2010). Meta-analytic findings suggest that emotion recognition impairments in ASD are independent of chronological age and cognitive ability, and are specific to certain emotions, with larger effects observed for negative emotions such as anger and fear, in comparison to positive emotions such as happiness (Uljarevic & Hamilton, 2013). Further, a recent study has suggested that this impairment may extend to neutral expressions, with ASD individuals displaying lower accuracy rates and slower detection speeds for neutral expressions, relative to neurotypical controls (Eack et al., 2015). Interestingly, Eack and colleagues reported that their ASD sample also displayed impairments when identifying happy expressions, however it is worthwhile noting that both ASD and neurotypical individuals displayed very high accuracy rates for happy expressions in this study, consistent with the assertion that happy expressions are the most easily recognised of the standard emotional expressions (Camras & Allison, 1985; Herba, Landau, Russell, Ecker, & Phillips, 2006).

In a similar vein to ASD, social avoidance and social interaction difficulties characterise SoAD, however these difficulties are largely driven by fear of negative evaluation by others (American Psychiatric Association, 2013). In contrast to findings in WS and ASD, individuals with SoAD do not seem to show impairments in emotion recognition, with SoAD individuals performing similarly to neurotypical controls on emotion recognition tasks, both in terms of accuracy rates and detection speed (Bell et al., 2011; Heuer et al., 2010; Peschard & Philippot, 2017). Similarly, as seen in neurotypical controls, high intensity expressions are better identified than low intensity expressions

(Philippot & Douilliez, 2005). While researchers are yet to conduct a direct comparison of emotion recognition ability in individuals with WS or SoAD, Wong et al. (2012) compared emotion recognition ability across children with high-functioning ASD or SoAD, using a combination of high and low intensity face stimuli. Results revealed no group differences in emotion recognition accuracy or detection speed, with all participants displaying higher accuracy rates for high intensity expressions compared to low intensity expressions, as well as faster detection of happy expressions, relative to angry, disgust and fearful expressions. Such findings have led to the suggestion that social avoidance in SoAD may be related to the evaluation of emotional expressions, rather than their perceived valence (Philippot & Douilliez, 2005).

In addition to overall emotion recognition ability, a related line of research has begun to explore interpretation biases in WS, ASD and SoAD by considering the types of misclassifications made in emotion recognition tasks, with a particular focus on neutral expressions. That is, do individuals with WS, ASD or SoAD tend to misclassify neutral faces as positive (e.g., happy) or negative (e.g., angry), and could this be related to some of the everyday social difficulties experienced by these individuals? To the best of our knowledge, no study to date has looked at the types of misclassifications made for neutral faces in WS individuals during emotion recognition tasks. However, previous findings suggest that WS individuals tend to misclassify fearful, angry and sad emotional expressions as happy more frequently than chronological-age matched neurotypical controls (Plesa Skwerer, Verbalis, et al., 2006; Porter et al., 2007). Further, as mentioned above, recent findings suggest that specific difficulties in identifying neutral expressions are seen in WS (Jarvinen, Ng, Crivelli, Neumann, et al., 2015). As Jarvinen and colleagues did not indicate whether this deficit in their WS sample was accompanied by an increased tendency to misclassify neutral faces as happy (or indeed, another emotion), a consideration of the types of misclassifications provided for neutral expressions by WS

individuals is warranted.

Considering the misclassification of neutral expressions in ASD and SoAD, there is growing evidence that individuals with these conditions display interpretation biases during emotion recognition tasks. Recent findings suggest that ASD individuals more frequently misclassify neutral expressions as angry when compared to neurotypical controls, which may be suggestive of a negative interpretation bias for facial expressions in this disorder (Eack et al., 2015). Moreover, while individuals with SoAD generally display intact emotion recognition abilities, numerous studies have found evidence for an increased sensitivity to threat-related expressions in this group, when looking at the types of misclassifications made for neutral expressions. SoAD individuals more frequently misclassify neutral faces as angry when compared to neurotypical controls (Bell et al., 2011; Gutiérrez-García & Calvo, 2017; Peschard & Philippot, 2017), leading to suggestions of a threat-interpretation bias in this group. Such a bias aligns with theoretical models of SoAD, which suggest that attention biases toward threat contribute to the maintenance of SoAD (Rapee & Heimberg, 1997). Moreover, findings from Wong et al. (2012) indicate that misclassifications for neutral expressions do not differ between children with ASD or SoAD.

Given the differential impairments in emotion recognition ability and misclassifications for neutral expressions reported across WS, ASD and SoAD, a cross-disorder comparison is warranted. Such a comparison would facilitate an understanding of unique impairments between individuals with WS, ASD or SoAD, which may in turn assist with the development of individually tailored therapies, such as social skills programs, for each population. Further, while the ability to accurately recognise facial emotional expressions is critical for effective social interactions, research has recently begun to consider other factors, such as biographical information known about a person, that may influence our recognition and evaluation of faces.

While the accurate identification of emotional expressions is critically important for effective social interactions, the context in which a facial expression is presented can influence both the recognition and evaluation of emotions. Research on neurotypical adults suggests that emotional expressions are more accurately identified when the perceiver believes they belong to an ingroup member (Young & Hugenberg, 2010), and learning person-based, biographical information about a face appears to have a particularly strong influence on subsequent perception and evaluation of that face. Specifically, learning negative biographical information about a face results in those faces subsequently being evaluated more negatively (Suess, Rabovsky, & Abdel Rahman, 2015), while associating neutral faces with positive or negative behaviours elicits neural reactivity in brain regions associated with emotion and social processing, such as the amygdala (Baron, Gobbini, Engell, & Todorov, 2011; Charmet-Mougey, Rich, & Williams, 2012). To date, this body of literature has not considered whether biographical information directly influences emotion recognition, or if it is secondary judgments and evaluations that are primarily influenced by such information. This question is of interest, as it would shed light on whether biographical information can directly influence our perception of emotional expressions; in essence, changing the way we 'see' the social world. Moreover, an investigation of emotion recognition abilities following such a manipulation in conditions such as WS, ASD and SoAD is warranted. Given the abnormalities in emotion recognition reported across these disorders, what is the influence of salient biographical information on immediate emotion recognition in these individuals?

To investigate the influence of biographical information on emotion recognition in individuals with WS, ASD or SoAD, we utilised faces that were perceptually neutral, but biographically salient. Participants learnt to associate perceptually neutral faces with either positive (trustworthy) or threatening (untrustworthy) biographical vignettes and were then presented with the same faces displaying happy, angry and neutral expressions to explore

group differences in emotion recognition following the manipulation of biographical information. To control for biographical memory, there was also a neutral condition comprising perceptually neutral face stimuli paired with neutral biographical vignettes.

Study Aims and Hypotheses

The present study compared emotion recognition abilities across individuals with WS, ASD or SoAD, as well neurotypical controls. The role of biographical information on emotion recognition abilities was also explored, in particular, whether previously learnt biographical information had any impact on emotion recognition in terms of detection speed or accuracy. We were also interested in whether biographical information influenced the type of misclassification.

Our first aim was to compare emotion recognition abilities across individuals with WS, ASD and SoAD, as well as neurotypical chronological age- and mental age-matched controls. In particular, we were interested in whether learnt biographical information had any impact on emotion recognition for happy, angry or neutral expressions in these groups, in terms of both detection speed and accuracy. We predicted that all groups would display faster reaction times and higher accuracy rates for happy expressions relative to angry and neutral expressions, and accuracy rates for happy expressions were expected to be similar across groups, given that happy expressions are easier to identify developmentally (Camras & Allison, 1985). We further hypothesised that individuals with WS would show slower reaction times across expressions compared to ASD and SoAD individuals, as well as controls matched on chronological age; instead displaying reaction times similar to those of mental-aged matched neurotypical controls. Slower response times for neutral expressions, but not for happy or angry expressions were anticipated in ASD individuals relative to neurotypical controls, while no differences in response time were expected between SoAD individuals and neurotypical controls. Accuracy rates for angry and neutral expressions in WS individuals were predicted to be lower than those in SoAD and

chronological-age matched individuals, and commensurate with neurotypical controls matched on mental age. Following from Jarvinen, Ng, Crivelli, Neumann, et al. (2015), we predicted that lower accuracy rates for neutral expressions would be observed in the WS group relative to the ASD group, however we did not anticipate differences in accuracy for angry expressions. Lower levels of accuracy for angry and neutral faces were expected in the ASD group relative to neurotypical controls, while similar levels of accuracy were expected in SoAD individuals and neurotypical controls. No differences in either response time or recognition ability were expected between ASD and SoAD individuals.

As prior research has not considered whether biographical information has the potential to interfere with emotion recognition accuracy or detection speed in these populations, we were interested in whether the detection of emotional expressions is influenced by previously learnt biographical information. Specifically, we investigated if congruency effects resulted in faster detection of expressions (e.g., happy expressions paired with trustworthy biographical information and angry expressions paired with untrustworthy biographical information), and, on the other hand, if incongruency effects resulted in slower detection of expressions (e.g. angry expressions paired with trustworthy biographical information and happy expressions paired with untrustworthy biographical information).

Our second aim was to compare group differences in the misclassification of neutral expressions, and, in particular, to explore whether biographical information influenced the type of misclassifications made for neutral faces. In line with prior research looking at misclassification rates, we predicted that WS individuals would more frequently misclassify neutral faces as being happy relative to all other groups. Conversely, we predicted that ASD and SoAD individuals would more frequently misclassify neutral faces as being angry relative to all other groups. Further, we predicted that biographical information would influence the type of misclassifications made, particularly for neutral

expressions. Specifically, we predicted that neutral faces paired with positive biographical information would be more frequently misclassified as happy, while neutral faces paired with threatening biographical information would be more frequently misclassified as angry. In line with reports of a positive social bias in WS (Dodd & Porter, 2010; Goldman et al., 2016), we anticipated that, while all groups would more frequently misclassify faces paired with positive biographical information as happy, this effect would be largest in the WS group. Further, following from the reports that ASD individuals may be prone to interpreting neutral expressions as negative (Eack et al., 2015), along with suggestions of a threat-related interpretation bias in SoAD (Gutiérrez-García & Calvo, 2017; Peschard & Philippot, 2017), we anticipated that, while all groups would more frequently misclassify neutral faces paired with threatening biographical information as angry, this effect would be largest in the ASD and SoAD groups.

Method

Participants

The study involved 73 participants (see below): 14 with WS, 15 with ASD, 15 with SoAD and 29 neurotypical controls (14 matched to WS participants on mental age and 15 matched to all clinical groups on chronological age). These participants were recruited for a series of studies, as reported in Boulton and Porter (2017); Boulton et al. (2018a, 2018c, 2018d). The mental age comparison group was included to accommodate the intellectual disability in the WS group. No evidence of intellectual disability was observed in either the ASD or SoAD group. We assessed verbal and spatial abilities for all participants using the Woodcock-Johnson Tests of Cognitive Ability – 3rd Edition (WJ-III COG; Woodcock, McGrew and Mather, 2001) (see below for details). Informed consent was obtained from the participants or their parents/caregivers, as appropriate. The study was approved by the Macquarie University Human Research Ethics Committee.

Williams syndrome group. Participants with WS (7 male, 7 female) aged between

13.42 and 43.75 years (*M*=21.07; *SD*=7.78) were recruited through Williams Syndrome Australia Limited. A diagnosis of WS had been confirmed in all participants following a positive fluorescent in situ hybridisation (FISH) test showing deletion of the elastin gene at 7q11.23 (Fryssira et al., 1997) and all participants exhibited the typical WS phenotype (Martens et al., 2008). Verbal ability standard scores using the Verbal Comprehension subtest from the WJ-III COG ranged from 56 to 91 (*M*=70.43; *SD*=9.78), while spatial-perceptual ability standard scores using the Spatial Relations subtest from the WJ-III COG ranged from 55 to 90 (*M*=76.43; *SD*=9.43)[3]. Exclusionary criteria for the WS group included a co-morbid neurological condition/insult or a clinical diagnosis that was not related to the primary diagnosis of WS. No participants met exclusionary criteria.

Autism spectrum disorder group. Participants with ASD (9 male, 6 female) aged between 11.00 and 42.50 years (*M*=25.98; *SD*=9.17) were recruited through Autism Spectrum Australia. A formal diagnosis of ASD had been made by a clinical psychologist and participants met criteria for ASD according to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5; American Psychiatric Association, 2013) confirmed by study authors MP or QW, qualified and registered psychologists. ASD participants also met clinical cut-offs for deficits in reciprocal social behaviour on the Social Responsiveness Scale-2nd Edition (SRS-2; Constantino & Gruber, 2012). For adolescent ASD participants, the School-Age Form was completed by parents, while adult ASD participants completed the Adult Self-Report Form. Further, the Ritvo Asperger and Autism Diagnostic Scale-Revised (RAADS-R; Ritvo et al., 2011) was administered to adult ASD participants. The RAADS-R is a self-report diagnostic measure, designed for

[3] Although scores on the Spatial Relations subtest of the WJ-III COG may seem higher than one would expect given the general cognitive profile seen in WS, performance on the equivalent version of this subtest in the Woodcock-Johnson Tests of Cognitive Ability-Revised has been found to be a cognitive strength in some subgroups of WS individuals (Porter & Coltheart, 2005). This is likely due to the absence of a construction component in this subtest, an area of functioning that is more commonly impaired in WS individuals (Porter & Coltheart, 2008).

assisting the diagnosis of ASD in adults with average intelligence. Consistent with a diagnosis of ASD, scores for all participants were above the diagnostic threshold of 65 on this measure (Ritvo et al., 2011). Verbal ability standard scores using the Verbal Comprehension subtest from the WJ-III COG ranged from 84 to 125 (*M*=107.00; *SD*=11.95), while spatial-perceptual ability standard scores using the Spatial Relations subtest from the WJ-III COG ranged from 94 to 133 (*M*=110.27; *SD*=9.07). Exclusionary criteria for the ASD group included a co-morbid neurological condition/insult or intellectual disability. No participants met exclusionary criteria.

Social anxiety disorder group. Participants with SoAD (1 male, 14 female) aged between 14.50 and 43.33 years (*M*=21.81; *SD*=6.91) were recruited through Macquarie University via advertisements placed around campus (*N*=8) and through the Centre for Emotional Health, a research and treatment clinic focused on treating and preventing mental health problems including anxiety, located at Macquarie University (*N*=7). The Anxiety and Related Disorders Interview Schedule for DSM-5 (ADIS-5; Brown & Barlow, 2014) was used to make a diagnosis of SoAD in adult participants, while the parent and child versions of the Anxiety Disorders Interview Schedule for Children for DSM-IV (ADIS-C/P; Silverman & Albano, 1996) were used to determine a diagnosis of SoAD in child participants. Trained clinicians, including co-author QW, conducted all interviews. Diagnoses were rated on a severity scale from 0 to 8, with a rating of 4 or higher indicating that the symptoms are causing significant life interference. Participants were included if SoAD was their principal diagnosis, with the presence of other anxiety and mood disorders allowed (13% of the SoAD group met criteria for an additional anxiety disorder and 53% met criteria for a mood disorder). Verbal ability standard scores using the Verbal Comprehension subtest from the WJ-III COG ranged from 93 to 120 (*M*=102.93; *SD*=8.05), while spatial-perceptual ability standard scores using the Spatial Relations subtest from the WJ-III COG ranged from 88 to 116 (*M*=100.40; *SD*=8.14). Exclusionary

criteria for the SoAD group included a neurodevelopmental disorder, such as ASD, a co-morbid neurological condition/insult or intellectual disability. No participants met exclusionary criteria.

Mental age comparison group. Participants were neurotypical children (7 male, 7 female) aged between 6.33 and 11.08 years (*M*=8.55; *SD*=1.41), recruited though the Macquarie University Neuronauts Kids Science Club, a register of children and adolescents who choose to take part in research projects at Macquarie University. Neurotypical children were matched to the WS group on mental age (MA) using an average of mental age equivalency on the verbal and spatial tasks (see below for task descriptions). Verbal ability standard scores using the Verbal Comprehension subtest from the WJ-III COG ranged from 94 to 107, (*M*=105.79; *SD*=9.42) and spatial ability standard scores using the Spatial Relations subtest from the WJ-III COG ranged from 91 to 114 (*M*=99.86; *SD*=7.62). Exclusionary criteria for the mental age comparison group included prior neurological condition or insult, a history of developmental delay, a history of intellectual disability (or current intellectual disability indexed by verbal or spatial ability scores ≤ 70 on the WJ-III COG), a clinical diagnosis (e.g., a psychological condition, or cognitive or sensory impairment), or a major or uncorrected sensory impairment that was likely to impact their performance on the research tasks . No participants met exclusionary criteria.

Chronological age comparison group. Participants were neurotypical individuals (4 male, 11 female) aged between 13.00 and 37.50 years (*M*=21.90; *SD*=6.02), recruited through the Macquarie University Neuronauts Kids Science Club or through the Macquarie University undergraduate psychology participation pool, a register of University students who participate in research in return for course credit. Neurotypical individuals were matched to the clinical groups on chronological age (CA). Verbal ability standard scores using the Verbal Comprehension subtest from the WJ-III COG ranged from 83 to 120,

(*M*=99.67; *SD*=7.85) and spatial ability standard scores using the Spatial Relations subtest from the WJ-III COG ranged from 89 to 121 (*M*=101.67; *SD*=6.35). The same exclusionary criteria were used as for the MA comparison group. No participants met exclusionary criteria.

Measures and Procedure

Woodcock-Johnson Tests of Cognitive Ability – 3rd Edition (WJ-III COG; Woodcock et al., 2001). To obtain an estimate of verbal and non-verbal (spatial-perceptual) ability, we used the Verbal Comprehension and Spatial Relations subtests from the Woodcock-WJ-III COG (Woodcock et al., 2001). Verbal Comprehension involves: naming objects; providing synonyms and antonyms for a range of words and completing verbal analogies. Spatial Relations requires participants to look at shapes and determine which pieces (from a selection of five options) would, when oriented correctly, join together to create the completed shape. These subtests have been found to reliably measure comprehension-knowledge (*Gc*) and visual-spatial thinking (*Gv*), with median reliabilities of 0.97 and 0.86, respectively (Woodcock et al., 2001).

Biographical learning task. The current study employed a biographical face learning paradigm, originally developed by Charmet-Mougey et al. (2012) for use in neurotypical adults. This paradigm has since been modified for use with neurotypical children and individuals with WS (Boulton & Porter, 2017) and has also been used successfully with ASD and SoAD populations (Boulton et al., 2018a). Images from 24 different actors (12 male, 12 female), displaying neutral expressions were displayed to participants. Images were selected from the NimStim standardised face set and all identities selected were reliably identified as expressing neutral expressions by independent raters (Tottenham et al., 2009). The 24 faces were divided into three blocks. A fictional biographical vignette was presented with each block of faces, describing the individuals as: (1) *trustworthy characters*, where the faces were described as belonging to

individuals who were trustworthy or 'good'; (2) *neutral characters,* where the faces were described as belonging to individuals who were neutral, or 'neither good nor bad'; and (3) *untrustworthy characters*, where the faces were described as belonging to individuals who were untrustworthy or 'bad'. Each block comprised four male and four female faces. The character types corresponding to each block were counterbalanced across participants to control for biases in responding. Counterbalancing was also employed to control for differences in perceived trustworthiness between faces.

To facilitate learning, separate training and testing phases were conducted. During the training phase, each block of faces was presented with a colour tint. LunaPic online picture editing software (www.lunapic.com) was used to tint each block blue, purple or orange. These colours were selected as they were considered to be relatively neutral and unlikely to be implicitly associated with emotionally salient information (Sutton & Altarriba, 2016; Takahashi & Kawabata, 2018). Colour tints were counterbalanced across conditions (blocks) and participants. Before each block of faces was presented, the corresponding biographical vignette (trustworthy characters, neutral characters, untrustworthy characters) was read aloud to the participant by the experimenter. Participants were instructed to look at each face until they believed they had memorised which character type it belonged to. Participants were able to look at the faces as many times as they liked and for as long as they liked. Once participants felt confident that they had memorised each face, the testing phase commenced. Each face was presented in greyscale and participants were asked to identify the character type of each face. Participants were provided with instant feedback after responding, and the emotion recognition task was not completed until participants were able to correctly label the character type of each face (when presented in greyscale) at an accuracy level of at least 80%. Participants were able to go back and look at the training stimuli (faces grouped according to vignette type with colour tints) as often as they liked in order to help them

remember the character type for each face. Once an accuracy level of at least 80% had been established for all participants, the emotion recognition experimental task was completed.

Emotion recognition experimental task. To assess emotion recognition abilities for faces paired with biographical information, we used an emotion recognition task similar to that used by Charmet-Mougey et al. (2012). In addition to the 24 faces displaying neutral expressions that were used in the biographical learning task, the happy and angry expressions for each of these faces were presented, resulting in a total of 72 faces. Overall there were nine character-emotion types: trustworthy-happy; trustworthy-neutral; trustworthy-angry; neutral-happy; neutral-neutral; neutral-angry; untrustworthy-happy; untrustworthy-neutral and untrustworthy-angry. The stimulus presentation was controlled using DMDX (Forster & Forster, 2003) and faces were presented on a Samsung 27-inch LED monitor from a distance of 60cm (viewing distance was controlled by seat position). The images measured 17.20 cm (650 pixels) wide by 22.09 cm (835 pixels) high and were presented in greyscale, with the hair showing. Each of the expressions was also displayed as a word (*happy*, *neutral/normal*, *angry*) that participants were asked to vocalise. The word 'normal' was provided for neutral faces to facilitate understanding of this expression in the WS and MA comparison groups. Participants were also provided with these expression terms in writing; options were printed in 24-point Times New Roman uppercase font affixed to the base of the monitor.

Participants were shown one face at a time, in a randomised order and were asked to identify the expression displayed by the face. The 72 faces were divided into three blocks of 24 trials; the order of expression (happy, neutral, angry) and character type (trustworthy, neutral, untrustworthy) were counterbalanced across blocks. Participants were fitted with a microphone, which was attached to a tube preamplifier to ensure quality recordings via the voice key feature in DMDX. Before each trial a fixation cross was

presented for 2,000ms, after which the face appeared. The face remained on the screen until a response was made or for 10,000ms. Reaction time (RT) data was recorded using the voice key. The experimenter manually noted any trials where i) the voice key malfunctioned (e.g. as a result of participant coughing or providing a response other than the options provided) or ii) an emotion recognition error was made (misclassification errors). Each trial was manually initiated by the experimenter. Three practice faces were shown initially to calibrate the voice key threshold and participants were given an opportunity to ask questions before the experimental trials began. In cases where the voice key malfunctioned, but participants provided a response, responses (but not RTs) were included in analyses.

Data preparation. Timing errors (trials where the voice key malfunctioned) and incorrect responses were removed. The percentage of trials excluded due to timing errors were: 3.89% (CA control group), 6.57% (ASD group), 7.69% (SoAD group), 10.02% (MA control group) and 12.10% (WS group), while the percentage of trials excluded due to incorrect responses were: 1.02% (CA control group), 1.94% (SoAD group), 3.98% (ASD group), 4.56% (MA control group) and 5.26% (WS group). Further, in line with previous research (Peschard & Philippot, 2017; Tseng et al 2017) RTs differing from a participant's individual mean RT by more than 3 standard deviations were removed. The percentage of trials subsequently excluded were: 1.02% (SoAD group), 1.39% (WS group), 1.48% (CA control group), 1.49% (MA control group) and 1.94% (ASD group).

Statistical Analysis

All statistical analyses were conducted using SPSS version 24 (IBM). With respect to demographic data, group differences on continuous variables, such as CA and MA, were explored using one-way analyses of variance (ANOVAs) and independent samples *t*-tests. Group differences on categorical variables, such as sex, were explored using Fisher's exact test. Between- and within-group differences for RTs were explored using repeated

measures ANOVAs. Due to violations of the assumptions of normality for emotion recognition accuracy rates and neutral misclassification rates, non-parametric tests were used to explore group differences for these variables. An a priori decision to only compare the MA-matched control group to the WS group was made, given that the rationale for including MA-matched neurotypical controls was to compare WS individuals to neurotypical controls matched on developmental level. Given the small sample size, and in an effort to minimise the likelihood of a Type-II error, corrections for multiple comparisons were not applied and alpha was set to 0.05 for all analyses (see Rothman, 1990). Cohen's *d* effect size estimates are reported for all parametric pairwise comparisons, with 0.2 indicating a small effect, 0.5 a medium effect, and 0.8 a large effect (Cohen, 1988).

Results

Demographic information for each group is displayed in Table 1. The WS, ASD SoAD and CA control groups did not differ significantly in chronological age (p=.28), nor did the WS and MA comparison groups differ significantly in mental age (p=.80). A sex difference was observed between the groups due to the SoAD group being predominantly composed of females (p=.02). A recent review suggests higher prevalence rates of SoAD, as well as elevated clinical severity of the disorder in women (Asher et al., 2017), which may explain the increased proportion of females in this sample. Excluding the SoAD group, the remaining groups were not found to differ on sex (p=.32). The percentage of trials excluded were: 6.34% (CA control group), 10.65% (SoAD group), 12.50% (ASD group), 16.07% (MA control group) and 18.75% (WS group). There was a significant group difference in the percentage of trials excluded, $F(4,68)=5.00$, p=.001. Tukey post hoc tests showed that the percentage of trials excluded in the CA group was significantly lower than those in the MA and WS groups (p=.018 and p=.001, respectively).

Group differences in verbal ability were observed; standard scores in the ASD,

SoAD, CA- and MA-matched comparison groups were significantly higher than those in the WS group (all p-values <.001). Similarly, group differences in spatial ability were observed; standard scores in the ASD group were significantly higher than those in the SoAD group (p=.021), while standard scores in the ASD, SoAD, CA- and MA-matched comparison groups were significantly higher than those in the WS group (all p-values <.001). Given the group differences in verbal and spatial ability, we assessed whether these variables were related to either RTs for emotional expressions, accuracy rates or misclassification rates for neutral expressions. Verbal ability correlated significantly with overall accuracy rates in the WS group only (r=–.85, p<.01). Spatial ability was not significantly related to RTs for emotional expressions, accuracy rates or misclassification rates for neutral expressions within any group (all p-values >.072). Whilst a standard approach in instances of between-group differences in cognitive ability is to control for cognitive ability statistically, this can increase Type-II error. Additionally, the suitability of including cognitive ability as a covariate when the relationship between cognitive ability and the dependent variable(s) of interest differs across groups has been brought into question (for a broader discussion see Dennis et al., 2009 and Miller & Chapman, 2001). Given that much of the literature covarys for cognitive ability in instances such as ours (although, see Jarivinen, Ng & Bellugi, 2015; Jarvinen et al., 2015 for recent exceptions), we conducted parametric analyses (our analytic approach did not enable us to include covariates in non-parametric analyses) with and without verbal and spatial ability included as covariates and found that the pattern of results did not differ. Thus, we report the results of the simple models without covariates. This methodology aligns with that recently employed by Chevallier et al. (2015) in ASD individuals.

Table 1

Demographic characteristics for each group.

	CA	ASD	SoAD	WS	MA	$p^{a,b,c}$
	n=15	*n*=15	*n*=15	*n*=14	*n*=14	
Chronological Age in years	21.90 (6.02)	25.98 (9.17)	21.81 (6.91)	21.07 (7.78)	8.55 (1.41)	0.28
Mental Age in years	–	–	–	8.14 (1.79)	7.97 (1.68)	0.80
Sex (n, % Female)	11 (73%)	6 (40%)	14 (93%)	7 (50%)	7 (50%)	0.02

Note: $^{a,b,c}p$-value for ANOVA (chronological age) independent samples *t*-test (mental age) and Fisher's exact test (sex) for any group differences. Data expressed as mean (SD). CA=Chronological age-matched controls; ASD=Autism Spectrum Disorder; SoAD=Social Anxiety Disorder; WS=Williams syndrome; MA=mental age-matched controls.

Reaction Times

Table 2 presents average RTs for each group as a function of biographical information. Differences in RTs were explored using a repeated measures ANOVA with Group as the between-subjects factor and Biographical Information (trustworthy, neutral, untrustworthy) and Emotion (happy, angry, neutral) as within-subjects factors. Results revealed significant main effects for Group, $F(4,68)=10.82$, $p<.001$, partial $\eta^2=0.39$, and Emotion, $F(2,136)=69.71$, $p<.001$, partial $\eta^2=0.51$, however the main effect of Biographical Information did not reach statistical significance ($p=.84$). There was a statistically significant interaction between Group and Emotion, $F(8,136)=2.68$, $p=.009$, partial $\eta^2=0.14$, however neither the Group by Biographical Information, nor the Emotion by Biographical Information interactions reached statistical significance, $p=.33$ and $p=.43$, respectively. Likewise, the three-way Group by Biographical Information by Emotion interaction did not reach statistical significance ($p=.35$). To decompose the significant Group by Emotion interaction, we looked separately at between- and within-group differences in speed of emotion recognition, independent of biographical information.

Considering between-group differences in RTs for emotional expressions, pairwise

comparisons revealed that, in comparison to WS individuals, CA-matched controls displayed significantly faster RTs for angry expressions, $t(68)=–2.41$, $p=.019$, $d=1.04$, and neutral expressions, $t(68)=–2.97$, $p=.004$, $d=1.44$. Similar findings were observed when comparing the SoAD and WS groups, with SoAD individuals showing significantly faster RTs for happy expressions, $t(68)=–2.29$, $p=.025$, $d=0.97$, angry expressions, $t(68)=–2.60$, $p=.011$, $d=1.02$, and neutral expressions, $t(68)=–3.13$, $p=.003$, $d=1.38$, relative to WS individuals. When comparing RTs between WS individuals and MA-matched controls, WS individuals were significantly faster for happy expressions, $t(68)=–2.68$, $p=.009$, $d=0.91$, angry expressions, $t(68)=–2.29$, $p=.011$, $d=0.67$, and neutral expressions, $t(68)=–2.90$, $p=.005$, $d=0.89$. In sum, WS individuals were significantly slower when identifying angry and neutral emotional expressions compared to both CA-matched controls and SoAD individuals, as well as showing slower RTs for happy expressions when compared to SoAD individuals. However, WS individuals were significantly faster when identifying all emotional expressions relative to MA-matched controls. No other pairwise comparisons reached statistical significance (all *p*-values >.056).

Looking at within-group differences in RTs for emotional expressions, all groups displayed significantly faster RTs for happy expressions compared to both angry and neutral expressions (all *p*-values <.047). While the MA-matched control and WS groups displayed significantly faster RTs for angry relative to neutral expressions (*p*-values .002 and .034, respectively), the CA-matched control, ASD and SoAD groups did not show statistically significant differences in the time taken to recognise angry, as opposed to neutral expressions (all *p*-values >.17).

Table 2

Average reaction times for each group on the emotion recognition task (milliseconds).

	CA	ASD	SoAD	WS	MA
Trustworthy BI					
Happy	803 (183)	812 (225)	785 (227)	934 (222)	1194 (376)
Angry	875 (226)	964 (205)	854 (242)	1080 (338)	1394 (388)
Neutral	929 (218)	976 (182)	861 (211)	1246 (264)	1613 (560)
Neutral BI					
Happy	759 (132)	866 (298)	732 (178)	919 (211)	1150 (356)
Angry	863 (141)	981 (269)	868 (263)	1144 (390)	1415 (595)
Neutral	918 (157)	1063 (433)	917 (232)	1200 (265)	1405 (378)
Untrustworthy BI					
Happy	802 (127)	902 (293)	767 (185)	974 (185)	1131 (232)
Angry	864 (149)	1015 (354)	820 (210)	1144 (263)	1301 (403)
Neutral	915 (185)	1061 (339)	938 (225)	1203 (282)	1514 (414)
All faces					
Happy	788 (132)	860 (248)	761 (191)	942 (181)	1158 (283)
Angry	867 (161)	987 (255)	847 (225)	1123 (307)	1370 (422)
Neutral	921 (171)	1033 (268)	905 (216)	1216 (234)	1511 (403)

Note: Data expressed as mean (SD). BI=Biographical Information; CA=Chronological age-matched controls; ASD=Autism Spectrum Disorder; SoAD=Social Anxiety Disorder; WS=Williams syndrome; MA=mental age-matched controls.

Emotion Recognition Accuracy

Table 3 shows the median and mean percentage emotion recognition accuracy for each group. We first considered group differences in emotion recognition accuracy for emotional expressions that had been paired with differing biographical information. Friedman's ANOVAs revealed no group differences (all *p*-values >.060), suggesting that biographical information did not influence emotion recognition accuracy for happy, angry or neutral expressions.

To address our predictions concerning group differences in emotion recognition independent of biographical information, we collapsed emotion recognition accuracy rates across biographical information. Although median accuracy rates for all groups were at or near ceiling level across expressions, as seen in Table 3, Kruskal Wallis tests revealed

significant between-group differences in emotion recognition ability for angry expressions, $H(4)=27.17$, $p<.001$, and neutral expressions, $H(4)=12.04$, $p=.017$. Mann Whitney tests were conducted to further explore these differences. Looking first at angry expressions, results revealed that CA-matched controls were more accurate at identifying angry expressions compared to WS ($U=62.0$, $p=.044$) and ASD ($U=54.0$, $p=.010$) individuals. Further, WS individuals were more accurate at identifying angry expressions when compared to MA-matched controls ($U=39.5$, $p=.006$). Considering neutral expressions, CA-matched controls were more accurate at identifying neutral expressions compared to WS ($U=47.5$, $p=.004$) and SoAD ($U=59.0$, $p=.010$) individuals. Additionally, ASD individuals were more accurate at identifying neutral expressions compared to WS individuals ($U=63.0$, $p=.044$). No other pairwise comparisons reached statistical significance.

With respect to within-group differences in emotion recognition accuracy, independent of biographical information, Friedman's ANOVAs revealed that the ASD, SoAD, WS and MA-matched control groups each displayed significant differences in emotion recognition ability (all p-values $<.014$)[4]. Follow-up Wilcoxon signed ranks tests indicated that the WS, ASD and MA-matched control groups displayed higher accuracy rates when identifying happy expressions as opposed to angry expressions (all p-values $<.048$). Additionally, the WS and SoAD groups displayed higher accuracy rates when identifying happy expressions as compared to neutral expressions ($Z=–2.51$, $p=.012$, and $Z=–2.58$, $p=.010$, respectively), while the MA-matched control group displayed higher accuracy rates when identifying neutral as opposed to angry expressions ($Z=–2.94$, $p=.003$).

[4] The CA-matched control group performed at ceiling level for all emotional expressions, only displaying minor variability for angry expressions (interquartile range = 4.2%).

Table 3

Median and mean accuracy rates (percentages) for each group on the emotion recognition task.

	CA	ASD	SoAD	WS	MA
Trustworthy BI					
Happy	100.0 (0.0)	100.0 (0.0)	100.0 (0.0)	100.0 (0.0)	100.0 (12.5)
	100.0 (0.0)	*97.5 (9.7)*	*100.0 (0.0)*	*96.4 (10.3)*	*96.4 (5.9)*
Angry	100.0 (0.0)	100.0 (0.0)	100.0 (0.0)	100.0 (12.5)	87.5 (15.6)
	99.2 (3.2)	*98.5 (5.2)*	*98.3 (4.4)*	*94.6 (8.1)*	*84.8 (10.0)*
Neutral	100.0 (0.0)	100.0 (0.0)	100.0 (0.0)	100.0 (18.8)	100.0 (12.5)
	99.2 (3.2)	*96.7 (7.4)*	*98.3 (4.4)*	*90.2 (15.6)*	*96.4 (5.9)*
Neutral BI					
Happy	100.0 (0.0)	100.0 (0.0)	100.0 (0.0)	100.0 (0.0)	100.0 (3.1)
	99.2 (3.2)	*98.3 (4.4)*	*99.2 (3.2)*	*100.0 (0.0)*	*96.4 (7.6)*
Angry	100.0 (0.0)	100.0 (12.5)	100.0 (12.5)	100.0 (12.5)	87.5 (25.0)
	98.3 (4.4)	*94.2 (8.0)*	*96.7 (5.7)*	*94.6 (6.4)*	*85.7 (11.9)*
Neutral	100.0 (0.0)	100.0 (0.0)	100.0 (0.0)	100.0 (12.5)	100.0 (3.1)
	100.0 (0.0)	*94.2 (16.9)*	*97.5 (5.2)*	*93.8 (11.8)*	*97.3 (5.3)*
Untrustworthy BI					
Happy	100.0 (0.0)	100.0 (0.0)	100.0 (0.0)	100.0 (0.0)	100.0 (3.1)
	100.0 (0.0)	*98.3 (4.4)*	*99.2 (3.2)*	*98.2 (4.5)*	*97.3 (5.3)*
Angry	100.0 (12.5)	87.5 (12.5)	100.0 (0.0)	100.0 (12.5)	87.5 (15.6)
	96.7 (5.7)	*90.8 (7.4)*	*97.5 (5.2)*	*94.6 (8.1)*	*89.3 (9.6)*
Neutral	100.0 (0.0)	100.0 (0.0)	100.0 (0.0)	100.0 (12.5)	100.0 (3.1)
	98.3 (6.5)	*96.7 (12.9)*	*95.8 (10.2)*	*90.2 (20.3)*	*97.3 (5.3)*
All faces					
Happy	100.0 (0.0)	100.0 (0.0)	100.0 (0.0)	100.0 (1.0)	95.8 (4.2)
	99.7 (1.1)	*98.1 (5.4)*	*99.4 (1.5)*	*98.2 (4.5)*	*96.7 (3.7)*
Angry	100.0 (4.2)	95.8 (4.2)	100.0 (4.2)	93.8 (8.3)	87.5 (16.7)
	98.1 (2.7)	*94.2 (4.4)*	*97.5 (3.5)*	*94.6 (4.7)*	*86.6 (7.7)*
Neutral	100.0 (0.0)	100.0 (4.2)	95.8 (8.3)	95.8 (24.0)	95.8 (5.2)
	99.2 (2.3)	*95.8 (10.8)*	*95.6 (4.8)*	*87.2 (16.9)*	*96.4 (4.0)*

Note: Data expressed as median (interquartile range). *Mean (SD)* displayed beneath median. BI=Biographical Information; CA=Chronological age-matched controls; ASD=Autism Spectrum Disorder; SoAD=Social Anxiety Disorder; WS=Williams syndrome; MA=mental age-matched controls.

Misclassification Rates for Neutral Expressions

To explore whether groups differed in the types of errors made for neutral

expressions, and whether this varied as a function of biographical information, we separated emotion recognition errors into two types of misclassifications, namely, neutral expressions misclassified as happy and neutral expressions misclassified as angry. Kruskal Wallis tests indicated no statistically significant group differences in neutral misclassifications, both for faces that had been paired with trustworthy biographical information and for faces that had been paired with untrustworthy biographical information (all *p*-values >.055).

To investigate group differences in neutral misclassifications independent of biographical information, we collapsed neutral misclassification rates (neutral as happy, neutral as angry) across biographical information. Kruskal Wallis tests revealed significant between-group differences in misclassification rates when neutral expressions were misclassified as happy, $H(4)=11.33$, $p=.020$, but not when neutral expressions were misclassified as angry, $H(4)=4.68$, $p=.322$. Follow-up Mann Whitney tests revealed that this difference was driven by more frequent misclassifications in the WS group, relative to the CA-matched control ($U=60.0$, $p=.005$) and SoAD ($U=65.5$, $p=.021$) groups. Examining the proportion of participants in each group who misclassified as least one neutral expression as happy, we found that 6 (43%) WS individuals made such a misclassification, in comparison to 0 (0%) CA-matched controls, 3 (23%) MA-matched controls, 3 (23%) ASD individuals and 1 (8%) SoAD individual ($p=.023$, two-tailed Fisher's exact test).

Discussion

The current study utilised a cross-disorder comparison to investigate emotion recognition ability in WS, ASD and SoAD. Further, as a novel manipulation we investigated whether emotion recognition was modulated by previously learnt biographical information. On the whole, while there was some evidence of group differences in response time and accuracy when identifying emotional expressions, the pattern of

responding was largely similar across the clinical and neurotypical groups, and previously learnt biographical information did not appear to influence either emotion recognition or the types of emotion misclassifications made for neutral expressions.

Within the clinical and neurotypical groups, happy expressions were accurately identified more quickly than either neutral or angry expressions. This finding is consistent with the prior literature in both clinical and neurotypical groups, with happy expressions generally identified more quickly and with higher accuracy relative to other emotional expressions (e.g. anger, fear) (Palermo & Coltheart, 2004; Plesa Skwerer, Verbalis, et al., 2006; Wong et al., 2012).

In line with our predictions, WS individuals took significantly longer to recognise angry and neutral expressions and displayed lower accuracy rates for these expressions, in comparison to CA-matched controls. However, the performance of the WS group appeared to be above what would be expected by their developmental level. That is to say, WS individuals identified all emotional expressions significantly faster than MA-matched controls, and outperformed the MA-matched group when identifying angry expressions, directly contrasting earlier findings of Porter et al. (2010), where WS individuals displayed a specific difficulty when recognising angry expressions compared to MA-matched controls. However, faster reaction times in the WS participants may have been influenced by their older chronological age relative to MA-matched peers; as noted by Plesa Skwerer, Faja, et al. (2006), one's social experiences can influence emotion recognition ability, which may have facilitated faster (and, for angry expressions, more accurate) emotion recognition in the WS group.

Somewhat in line with our prediction, ASD individuals showed lower accuracy rates for angry but not neutral expressions compared to neurotypical controls. Further, accuracy was very high in the ASD group overall. Our use of a high-functioning ASD sample is unlikely to explain this finding, with a recent meta-analysis suggesting that

emotion recognition in ASD is unrelated to level of functioning (Uljarevic & Hamilton, 2013). Additionally, deficits in identification of happy and neutral expressions have been found to occur in high-functioning individuals with ASD when compared to neurotypical controls with similar (indeed, slightly lower) cognitive ability (Eack et al., 2015), and it has been suggested by some, but not all (e.g. see Griffiths et al., 2017) researchers that larger emotion recognition difficulties in ASD are only detectable when low intensity stimuli are used (Law Smith, Montagne, Perrett, Gill, & Gallagher, 2010). Given that the NimStim face stimuli are considered high intensity (Tottenham et al., 2009), this may explain the high accuracy rates across groups and expressions.

As anticipated, SoAD individuals were significantly faster to identify all emotional expressions compared to WS individuals. No differences in response time across emotional expressions were observed between the ASD and WS groups, although ASD individuals outperformed WS individuals when identifying neutral expressions, in line with the findings of Jarvinen et al. (2015). Of note, no differences in accuracy rates for happy or angry expressions were observed between the clinical groups, suggesting that individuals with WS, ASD or SoAD are able to recognise happy and angry expressions at similar levels of accuracy, at least when faces displaying high intensity expressions are used.

Interestingly, accuracy rates for all emotional expressions across the clinical groups were at or near ceiling level, largely mirroring the pattern seen in neurotypical controls and suggesting that emotion recognition for high intensity happy, angry and neutral expressions is generally intact across these conditions. While accuracy scores were higher in the current study relative to previous studies, particularly within the WS literature (Gagliardi et al., 2003; Plesa Skwerer, Faja, et al., 2006), this likely reflects our use of only high intensity face stimuli, as well as the limited range of expressions presented to participants. Previous studies have presented a combination of high and low intensity stimuli (Plesa Skwerer, Faja, et al., 2006), as well as a greater variety of emotional expressions (e.g. fear,

sadness) (Gagliardi et al., 2003). Although the use of a forced-choice paradigm may have made the task easier for participants given that there were only three possible options to choose from, previous studies within the WS (Porter et al., 2010), ASD (Eack et al., 2015), and SoAD (Bell et al., 2011) literature have adopted similar methods, suggesting that higher accuracy rates cannot be fully attributed to this methodological decision.

Given the evidence suggesting a threat-related interpretation bias in ASD and SoAD, such that neutral faces have been found to be more commonly misclassified as angry in individuals with ASD or SoAD (Eack et al., 2015; Gutiérrez-García & Calvo, 2017; Peschard & Philippot, 2017), alongside the apparent positive bias in WS, where happy faces are preferentially attended to (Goldman et al., 2016) and fewer negative attributions are made (Godbee & Porter, 2013), we also investigated group differences in misclassifications for neutral emotional expressions. Counter to our predictions, neither ASD nor SoAD individuals displayed a tendency to misclassify neutral expressions as threatening (angry). While this finding may be reflective of the ease of the task (both ASD and SoAD participants made very few emotion recognition errors overall), it should also be noted that ASD and SoAD individuals do not consistently misclassify neutral faces as angry throughout the literature (Button, Lewis, Penton-Voak, & Munafo, 2013; Wong et al., 2012), due perhaps to the heterogeneity within the disorders, as well as the diversity of paradigms and stimuli employed across studies.

While the tendency to misclassify neutral expressions as happy was generally low across groups, our findings suggest that WS individuals more frequently made this type of misclassification error compared to both SoAD individuals and CA-matched controls. Whilst consistent with our predictions, we nonetheless recommend caution when interpreting this finding, given that a substantial proportion of our WS group (eight out of fourteen) did not misclassify neutral faces as happy, and the WS group in general displayed high accuracy rates for neutral expressions. However, this heterogeneity is

compelling, and raises the question of whether individual variability in the misclassification of emotional expressions may contribute to the striking social phenotype characteristic of WS. That is, do some individuals with WS differ in the emotions they 'believe' to see, and does this co-occur with other social-behavioural abnormalities, such as increased approach behaviours?

The current findings suggest that biographical information does not influence emotion recognition ability in WS, ASD, SoAD or neurotypical individuals, at least when high intensity happy, angry and neutral expressions are used. That is, congruent emotional-biographical pairings did not facilitate faster and more accurate emotion recognition, nor did incongruent emotional-biographical pairings result in slower and less accurate emotion recognition. There was also no apparent influence of biographical information on the types of misclassification errors made for neutral expressions. There are two possible, and complimentary, explanations for this finding. Firstly, we utilised high intensity happy, angry and neutral face stimuli, making this task considerably easier than previous paradigms administered with these groups, which have featured additional expressions (such as fear and sadness), as well as stimuli of varying intensity (e.g., see Eack et al., 2015; Philippot & Douilliez, 2005; Plesa Skwerer, Faja, et al., 2006). Given the relative simplicity of the task (high intensity faces and only three expressions to choose from), it is likely that participants solely used bottom-up processing when identifying expressions, providing responses rapidly and automatically based on the perceptual information presented, with emotional expressions identified before top-down processing could occur. Secondly, the perception and emotion processing literature has recently proposed that biographical information is more likely to influence judgments surrounding the semantic valence of a face (for example, how 'likeable' it is), rather than directly influencing or distorting the perception of the emotional expression (Lazerus, Ingbretsen, Stolier, Freeman, & Cikara, 2016). If this is the case, then one would expect that, while learnt

biographical information may not necessarily influence emotion recognition, it may influence subsequent social interactions, such as the decision of whether to approach or avoid another person.

Methodological Considerations and Future Directions

The present findings need to be considered within the context of certain methodological limitations. First, our sample size was small, despite being comparable to recent studies with WS individuals (Goldman et al., 2016; Hirai et al., 2017), as well as previous cross-disorder comparisons between WS and ASD (Jarvinen, Ng, Crivelli, Neumann, et al., 2015; Riby & Hancock, 2009b). Further, we were unable to match our participants on sex in the current study, due to the increased prevalence of SoAD in females (Asher et al., 2017), however, all groups were well matched on chronological age, and our WS group was also compared to a comparison group matched on mental age, consistent with much of the WS literature (Hirai et al., 2017; Riby et al., 2011). Given the novelty of the biographical learning task used in this study, as well as the relative lack of cross-disorder comparisons between WS, ASD and SoAD, replication of these findings with larger samples would be particularly informative.

While it must be acknowledged that the ceiling effects observed in the current study limit our interpretations about differences in emotion recognition ability between WS, ASD and SoAD individuals, our results are largely consistent with previous literature, where high accuracy rates for high intensity emotional expressions have been reported across WS (Porter et al., 2010), ASD (Eack et al., 2015), and SoAD (Philippot & Douilliez, 2005) populations. Future research may benefit from incorporating additional emotional expressions, such as fear and disgust, as well as utilising stimuli of varying intensities, in order to better tease apart more subtle emotion recognition difficulties across WS, ASD and SoAD.

Additionally, while a limited amount of prior research has considered how

biographical information can influence face evaluation and emotion recognition, particularly of neutral expressions, in neurotypical individuals, this was the first study to apply such a concept to individuals with neurodevelopmental or anxiety disorders. As our use of high intensity stimuli may have contributed to the high accuracy rates observed across groups and emotional expressions, employing low intensity stimuli may help to tease apart the effect of biographical information on emotion recognition, as participants may not identify low intensity expressions as readily, and may recruit the biographical information previously learnt about the face, thereby engaging in top-down processing. Similarly, using dynamic stimuli with emotional expressions that morph from neutral to happy or angry may prime the biographical information of the face, which in turn may facilitate top-down processing. Further, functional neuroimaging studies would benefit from manipulating biographical information, as well as emotional expression, when considering neural substrates of face and emotion processing in WS, ASD and SoAD. Specifically, given the role of the amygdala in bottom-up processing and emotion perception (Adolphs, 2002), alongside the amygdala anomalies in response to emotional faces reported across these conditions (see Barak & Feng, 2016; Binelli et al., 2014 for reviews), an investigation of amygdala reactivity to faces paired with positive or threatening biographical information would be particularly informative.

Of note, while cross-disorder comparisons provide us with a crucial understanding of features that are shared between disorders or specific to a condition, one cannot ignore the heterogeneity within WS, ASD and SoAD, which likely contributes to the fractionated findings across the literature. Fine-grained analyses of findings, taking individual differences into account are warranted, in order to further understand which features of social behaviour are unique to certain individuals, and which are more representative of a condition as a whole.

In conclusion, the current study is the first to conduct a cross-disorder comparison

of emotion recognition abilities in WS, ASD and SoAD, with our findings suggesting that the ability to recognise high intensity emotional expressions is relatively intact across these conditions. Further, our study suggests that some individuals with WS may demonstrate a positive interpretation bias when identifying neutral expressions, consistent with prior findings of a positive social bias in this group. Moreover, building on findings suggesting that previously learnt biographical information can influence subsequent social judgments and evaluations in neurotypical individuals, our study is the first to explore the role of biographical information on subsequent emotion recognition and provides evidence that the perception of static, high intensity emotional expressions is not influenced by previously learnt biographical information in individuals with WS, ASD or SoAD.

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Paper 4

Visual Attention and Executive Functioning in Williams syndrome, Autism Spectrum Disorder and Social Anxiety Disorder: The Role of Biographical Information

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Abstract

Abnormalities in visual scanpaths and executive functioning are observed in Williams syndrome (WS), Autism Spectrum Disorder (ASD) and Social Anxiety Disorder (SoAD). A cross-disorder comparison of visual attention for biographical faces was conducted and associations between attentional capture, attentional disengagement and executive functioning were investigated. 75 individuals (15 WS, 15 ASD, 15 SoAD, 30 neurotypical controls) learnt to associate perceptually neutral faces with trustworthy or untrustworthy biographical information, before completing an eye-tracking task with the same faces. Questionnaire measures of everyday executive functioning were administered to clinical groups. Compared to ASD individuals and neurotypical controls, WS individuals demonstrated difficulties disengaging their attention from the eyes of faces paired with trustworthy biographical information. The eyes of all faces captured the attention of SoAD individuals faster than neurotypical controls. While relationships between executive functioning capabilities and both attentional capture and disengagement were observed in WS individuals, results suggest that executive functioning was associated with only attentional capture for SoAD individuals and only attentional disengagement for ASD individuals. Findings highlight the benefits of cross-disorder comparisons to better understand social attention abnormalities in conditions where social functioning is impaired.

Visual Attention and Executive Functioning in Williams syndrome, Autism Spectrum Disorder and Social Anxiety Disorder: The Role of Biographical Information

Introduction

Key features of neurodevelopmental or anxiety disorders include social dysfunction and diminished interpersonal relationships (Aderka et al., 2012; Jawaid et al., 2012). Individuals with Williams syndrome (WS) invariably display increased sociability, treating everyone as though they are a friend (Thurman & Fisher, 2015), while individuals with Autism Spectrum Disorder (ASD) or Social Anxiety Disorder (SoAD) commonly display difficulties interacting with others and social avoidance (American Psychiatric Association, 2013; Chevallier et al., 2012). In addition to these contrasting social profiles, one striking observation across these disorders, reported both clinically and anecdotally, pertains to eye contact. In WS, intense eye contact is common, with individuals known to strike up conversations with strangers whilst staring intently into their eyes (Jones et al., 2000). In contrast, in ASD and SoAD, eye contact is avoided, eliciting feelings of fear (Schneier, Rodebaugh, Blanco, Lewin, & Liebowitz, 2011) and distress (Trevisan et al., 2017). Moreover, although WS, ASD and SoAD each show distinctive social profiles, the impairments in everyday social functioning are remarkably similar across disorders, with difficulties in developing and maintaining relationships, as well as social isolation reported (Fisher & Morin, 2017; Orsmond, Shattuck, Cooper, Sterzing, & Anderson, 2013; Rodebaugh, 2009). Persisting across the lifespan, these impairments have negative consequences for the social ability and mental health of affected individuals (Hofvander et al., 2009; Howlin & Udwin, 2006; Wittchen, 2003).

Early Social Attention in WS, ASD and SoAD: The Importance of the Eyes

Successful social interactions require us to perceive, comprehend and respond to facial information automatically and instantaneously (Itier & Batty, 2009). In neurotypical adults, this process is facilitated by utilising a specific pattern of eye movements when

looking at a face; fixating on the salient features of the eyes, nose and mouth, resulting in the classic 'inverted triangle' scanpaths (Walker-Smith, Gale, & Findlay, 1977). Given the social functioning difficulties seen across WS, ASD and SoAD, in conjunction with the atypical eye contact reported in these groups, a substantial amount of research has considered whether attention to faces, known also as social attention, is abnormal in individuals with these disorders. For instance, do WS individuals show increased attention to faces relative to neurotypical controls, and may this underpin the renowned hypersociability in this group? In contrast, do ASD or SoAD individuals display decreased attention to faces or increased attention specifically to threatening faces, thereby perpetuating the social avoidance seen in these populations? Similarly, the way in which individuals with WS, ASD or SoAD attend to certain salient features within the face itself, such as the eyes, has become a topic of considerable interest. Abnormalities in the initial allocation of attention to the eyes, as well as atypical patterns of attentional disengagement away from the eyes, may well contribute to the social functioning difficulties seen in WS, ASD and SoAD.

In WS, a neurodevelopmental disorder caused by a microdeletion on chromosome 7 at 7q11.23 (Ewart, 1993), faces seem to be particularly salient, in line with the gregarious personality and desire to be around others often seen in these individuals (Thurman & Fisher, 2015). This intense interest in both familiar and novel faces begins in infancy (Mervis et al., 2003) and has been observed experimentally using numerous paradigms. Considering social attention using eye-tracking in this group, Riby and Hancock found that individuals with WS spent more time looking at faces compared to both neurotypical controls and individuals with ASD (Riby & Hancock, 2008, 2009b) . Of note, the authors found that faces did not seem to capture the attention of individuals with WS, rather, it appeared as though WS individuals were spending longer looking at faces once they had been fixated upon, as though their attention was 'stuck' on the face (Riby & Hancock,

2009a). Following up on this initial finding of prolonged face fixation, Riby and colleagues confirmed that the abnormal, increased social attention in their WS sample was driven by difficulties disengaging attention from faces (Riby et al., 2011). Further evidence of increased social attention resulting from attentional disengagement difficulties in WS has come from studies employing the dot-probe paradigm. Dodd and Porter (2010) found that, not only did WS individuals display difficulties disengaging attention from faces compared to neurotypical controls (similar to eye-tracking findings above), but also that the increased social attention observed was exclusive for happy faces, suggesting that positive (happy) faces appear to hold particular salience for WS individuals and are, thus, preferentially attended to. However, it should be noted that within-syndrome heterogeneity has been observed, with attentional biases and visual attention to faces varying between WS individuals as a function of anxiety and cognitive ability (Kirk et al., 2013; McGrath et al., 2016). Moreover, recent evidence from dot-probe paradigms suggests that, for some WS individuals, happy faces may capture attention (Goldman et al., 2016) and attentional disengagement difficulties from faces may be seen only in certain WS individuals (Boulton & Porter, 2017), further highlighting the heterogeneity within this population.

Given the importance of the eyes for informing social interactions (Pfeiffer, Vogeley, & Schilbach, 2013), coupled with anecdotal reports of unusually intense eye contact in WS, eye-tracking research has also considered whether individuals with WS show increased interest in the eye region of faces. Earlier findings suggested that WS individuals spend significantly longer looking at the eye regions of faces compared to both neurotypical individuals, as well as individuals with ASD (Riby & Hancock, 2008, 2009b). Further, considering the role of emotional expression, Porter et al. (2010) found that WS individuals display longer fixations to the eye region across neutral, happy, angry and fearful emotional expressions, most likely driven by attentional disengagement difficulties. However, Porter and colleagues commented on the variability within their WS sample in

terms of eye scanpaths and recent findings also suggest that a tendency to fixate on the eyes may not be characteristic of all WS individuals. For example, when required to identify mental states from faces, some WS individuals spend less time looking at the eye region relative to neurotypical controls (Hanley et al., 2013). While this may be reflective of the clinical heterogeneity common in WS, there is evidence that WS individuals engage in gaze aversion as a strategy to manage cognitive load (Doherty-Sneddon, Riby, & Whittle, 2012). As Hanley and colleagues were the first to record eye-movements in WS individuals during a cognitive task (as opposed to passive viewing), this may explain the apparent discrepancies. Of course, both explanations are plausible and are not mutually exclusive.

In contrast to the hypersociability and increased social interest seen in WS, social avoidance and decreased social motivation are considered hallmarks of ASD (Chevallier et al., 2012) and faces, specifically the eyes, are generally avoided (Black et al., 2017). Individuals with ASD display reduced gaze towards faces compared to both WS individuals and neurotypical controls (Riby & Hancock, 2008, 2009b). Moreover, studies utilising the dot-probe paradigm have generally reported no evidence that faces capture the attention of these individuals, nor that ASD individuals experience difficulties disengaging attention from faces (May et al., 2015), although findings vary as a function of presentation time (Garcia-Blanco et al., 2017) and stimulus type (Zhao, Zhang, Fu, & Maes, 2016). Considering attention patterns to specific face regions, earlier eye-tracking studies found that ASD individuals spent less time looking at salient areas of the face (eyes, nose, mouth) and more time looking at non-salient features (e.g. hair, chin), compared to neurotypical controls (Pelphrey et al., 2002). Whilst this finding has not been consistently reported (e.g. see McCabe et al., 2013), a recent meta-analysis suggests that ASD individuals do spend less time looking at salient face regions relative to controls, however effect sizes are generally small (Chita-Tegmark, 2016).

In line with the unusual face scanpaths reported, decreased eye contact is considered a key characteristic of ASD (American Psychiatric Association, 2013) and is observed from infancy, with two-year-old ASD individuals spending less time looking at the eyes of others compared to individuals matched on chronological age or developmental level (Jones, Carr, & Klin, 2008). Attenuated eye contact continues across the course of development; children with ASD spend less time looking at the eyes of faces, across both positive and negative emotional expressions, when compared to neurotypical controls (see Papagiannopoulou, Chitty, Hermens, Hickie and Lagopoulos (2014) for a meta-analysis), as do adults with ASD (see Black et al., 2017, for a review). Further, it has been suggested that eye contact may be actively avoided by those with ASD, with findings suggesting that ASD individuals are more likely to gaze away from the eye region, rather than towards the eye region, in comparison to neurotypical individuals (Kliemann et al., 2012). It has recently been proposed that this avoidance of the eye region may serve as an adaptive strategy for ASD individuals, given the discomfort associated with direct eye contact in this group (Tanaka & Sung, 2016). Moreover, there is evidence that some ASD individuals may preferentially allocate their attention to the mouth in an attempt to compensate for eye avoidance, with ASD individuals displaying increased viewing time to the mouth region when compared to neurotypical controls (Spezio, Adolphs, Hurley, & Piven, 2007), however this finding is not consistently reported (Hanley, McPhillips, Mulhern, & Riby, 2013).

In SoAD, a psychological condition affecting approximately 8.4% of Australians at some point in their lives (Crome et al., 2015), threatening faces appear to be particularly salient, consistent with the recurrent fear of negative evaluation which characterises this disorder (Hofmann et al., 2015). Theoretical models of social anxiety propose that individuals with SoAD selectively allocate their attention to threat and experience difficulties disengaging attention from threat, a pattern that serves to maintain social

anxiety and likely perpetuates the avoidance of social situations (Rapee & Heimberg, 1997; Wong & Rapee, 2016). These models have received empirical support, with experimental paradigms reporting attentional biases for threatening (angry) faces (see Bantin, Stevens, Gerlach & Hermann, 2016 for a recent meta-analysis), as well as increased initial orienting towards threatening faces when multiple faces, varying in valence, are presented (for a recent review see Chen & Clarke, 2017). Aligning with the avoidance of eye contact reported clinically in SoAD, eye-tracking studies have found that, compared to neurotypical controls, SoAD individuals spend less time overall looking at the eye regions of faces, with the strongest effects observed for angry faces (Chen & Clarke, 2017; Moukheiber et al., 2010). However, this overall avoidance appears to be preceded by an initial vigilance for the eyes. Recent findings indicate that SoAD individuals display hypervigilance for the eye region of faces displaying various emotional expressions at early attentional stages relative to neurotypical controls (Boll et al., 2016; Gutierrez-Garcia, Calvo, & Eysenck, 2018), suggesting that the eyes do capture attention, at least initially, in SoAD individuals.

As can be ascertained from the literature reviewed above, previous research suggests that attention patterns for faces in WS, ASD or SoAD correspond, at face value, to the distinctive social profiles seen in these disorders, that is, hypersociability and increased social interest in WS, alongside hyposociability and social avoidance in ASD and SoAD. Further, while much of the research to date has investigated the processes influencing social attention within a single disorder, often in comparison to neurotypical controls matched on chronological age or developmental level, cross-disorder comparisons are less common. By directly comparing social attention between disorders that show different social profiles, we can further our understanding of the mechanisms at play in social approach and avoidant behaviours. Additionally, given that the functional social impairments seen in WS, ASD and SoAD appear to be similar despite discrete social

profiles, a more nuanced understanding of the underlying processes that contribute to these impairments, such as attention for faces, is warranted.

Social Dysfunction in WS, ASD and SoAD: The Role of Executive Functioning

Whilst the above evidence outlines the importance of social attention, specifically, early social attention to the eye region, in social functioning, a separate body of research has considered how cognitive processes also contribute to social interactions. One set of cognitive processes that have received attention across the WS, ASD and SoAD literature are executive functions. Executive functions are thought to be involved in social, emotional and behavioural abilities and include a set of distinct, yet related processes: inhibition; shifting (or cognitive flexibility); emotional control; planning and organisation; initiation and working memory (Miyake et al., 2000). Together these processes are involved in the coordination and regulation of goal-directed behaviours. Delays and impairments in everyday executive functioning have been reported in WS (Hocking et al., 2015), ASD (Hill, 2004) and in SoAD (Judah, Grant, Mills, & Lechner, 2013). Further, it has been theorised that successful social interactions rely on intact executive functioning (Moriguchi, 2014). For instance, initiating and maintaining a conversation with another person necessitates the ability to flexibly shift between topics, inhibit irrelevant or inappropriate responses, hold relevant information about the conversational topic in mind and appropriately modulate emotions to match the tone of the conversation.

Given the social functioning impairments seen across WS, ASD and SoAD, it is not surprising that research has begun to link difficulties in various executive functioning processes with social dysfunction in each disorder. In WS, impairments in response inhibition have been linked to inappropriate social approach behaviours (Little et al., 2013; Porter et al., 2007), while deficits in shifting may give rise to difficulties disengaging attention from faces (Dodd & Porter, 2010; Riby et al., 2011). Further, recent findings suggest that executive functioning difficulties, particularly those thought to be involved in

behavioural regulation, are associated with impairments in social functioning in WS individuals (Ng-Cordell et al., 2018). In ASD, impairments in behavioural regulation, such as inhibition and set shifting, as well as deficits in metacognitive executive processes, such as initiation, as well as planning and organisation are associated with functional social impairments and poorer friendship quality (Leung et al., 2016; Lieb & Bohnert, 2017). Finally, in SoAD, attentional control theory posits that impairments in inhibition underlie the initial vigilance for threatening faces reported, while deficits in shifting contribute to the difficulties disengaging initial attention from threatening faces (Eysenck et al., 2007). Additionally, within SoAD individuals, greater impairments in shifting are related to increased symptom severity (Fujii et al., 2013). Taken together, these findings are suggestive of a relationship between executive functioning and social functioning, such that impairments in executive functioning may contribute to the compromised social functioning seen across WS, ASD and SoAD. Moreover, executive functions are believed to be critically involved in the generation of voluntary eye movements and top-down attentional control (Sereno, Babin, Hood, & Jeter, 2009), suggesting that impairments in executive functioning may contribute to abnormal visual scanpaths. Given the atypicalities in social attention observed in individuals with WS, ASD and SoAD, and the subsequent social dysfunction seen across these disorders, a consideration of whether executive functioning impairments are related to social attention, specifically, visual attention to the eye region, in individuals with these disorders is warranted.

The Current Study

When considering social attention in WS, ASD or SoAD, research to date has largely utilised face stimuli displaying varying emotional expressions. While emotional expressions aid in our evaluations of others during social interactions, they are not the only person-based feature we use when navigating the social world, nor are they the only possible manipulation of socially positive versus socially threatening stimuli. For instance,

biographical information learnt about a person can be equally informative when determining the potential threat posed by a person in day to day social interactions. Indeed, research in neurotypical adults suggests that associating neutral faces with positive or negative behaviours influences subsequent evaluation and likeability ratings of the same faces (Abdel Rahman, 2011; Verosky et al., 2018), as well as eliciting neural reactivity in brain regions associated with emotion and social processing, such as the amygdala and superior temporal sulcus (Baron, Gobbini, Engell, & Todorov, 2011; Charmet-Mougey, Rich, & Williams, 2012). Given that visual scanpaths appear to be modulated, to varying degrees, by emotional expressions in WS, ASD and SoAD, we were interested in using faces that were perceptually neutral, but biographically salient, to determine the influence of biographical information on visual scanpaths in these disorders. Group differences in visual scanpaths for trustworthy characters – perceptually neutral face stimuli paired with trustworthy biographical vignettes and untrustworthy characters – perceptually neutral face stimuli paired with untrustworthy biographical vignettes, were explored. There was also a neutral condition comprised of perceptually neutral face stimuli paired with neutral biographical vignettes to control for biographical memory.

In light of the extant literature, the aims of the present study were twofold. The first aim was to explore visual scanpaths towards salient face regions across individuals with WS, ASD or SoAD, as well as neurotypical controls, manipulating the biographical information associated with the face, rather than the more commonly used manipulation of emotional expression. Based on the above literature, we hypothesised that WS individuals would spend more time looking at salient face features in comparison to ASD, SoAD and neurotypical individuals, while ASD individuals were expected to spend less time looking at salient features, compared to WS individuals and neurotypical controls. In line with existing literature in WS and ASD, albeit looking at emotional expressions, these abnormalities were not expected to be influenced by biographical information (Black et al.,

2017; Porter et al., 2010). In the SoAD group, however, building on prior findings in SoAD, albeit where emotional expressions have been utilised (see Chen & Clarke, 2017, for a review), we anticipated that decreased time spent looking at salient features over the whole viewing period would be most evident for faces paired with untrustworthy biographical information when the scanpaths of these individuals were compared with those of neurotypical controls.

Given the importance of the eye region for guiding social interactions, our second aim was to explore initial attention patterns to the eye region and, in particular, whether initial attention to the eye region varied according to the biographical information previously paired with the face. Specifically, we were interested in how quickly initial fixations to the eye region were made (attentional capture) and the duration of initial fixations in the eye region before shifting attention elsewhere (attentional disengagement). In line with prior eye-tracking research (e.g., Porter et al., 2010), we predicted that the eye region of faces would not capture the attention of WS individuals, but that WS individuals would show difficulties in disengaging their attention from the eye region of faces, regardless of the type of biographical information paired with the face, both in comparison to neurotypical controls and ASD individuals. We further hypothesised that, irrespective of the biographical information paired with the face, ASD individuals would display no evidence of attentional capture towards the eye region, and would shift their attention away from the eye region more rapidly than all other groups, in line with the eye avoidance hypothesis proposed by Tanaka and Sung (2016). Finally, following from the findings of Boll et al. (2016), we predicted that, relative to ASD individuals and neurotypical controls, the SoAD group would display faster attentional capture to the eye region of all faces, irrespective of the type of biographical information paired with the face, as well as difficulties disengaging their attention from the eye region of faces, particularly those paired with untrustworthy biographical information, in line with theoretical models of

threat processing in SoAD (Rapee & Heimberg, 1997). While no research to date has directly compared visual attention in WS and SoAD individuals, based on their discrete social profiles and our predictions in terms of attentional capture and disengagement relative to neurotypical controls, we predicted that attentional capture for faces paired with untrustworthy biographical information would be more evident in SoAD, relative to WS, while no group differences in attentional disengagement were expected for these faces.

Further, based on recent literature suggesting a link between executive functioning difficulties and social dysfunction across these disorders (Fujii et al., 2013; Leung et al., 2016; Ng-Cordell et al., 2018), alongside the critical role of executive functioning in attentional control and the generation of eye movements (Sereno et al., 2009), we also investigated the relationship between everyday executive functioning processes and initial attention to the eyes within the clinical groups. Specifically, we were interested in whether executive functioning difficulties were differentially associated with atypical patterns of attentional capture or disengagement in those with WS, ASD or SoAD. Given the lack of research in this area, no specific hypotheses were made.

Method

Participants

The current study comprised 75 participants: 15 with WS; 15 with ASD; 15 with SoAD, and 30 neurotypical participants (15 matched to the clinical groups on chronological age and 15 matched to the WS group on mental age). These participants were recruited for a series of studies, as reported in Boulton and Porter (2017); Boulton et al. (2018a, 2018b, 2018d). WS, ASD, SoAD and chronological-age matched control participants were matched at a group level on chronological age (CA); while WS and mental-age matched control participants were matched at a group level on mental age (MA). An estimate of verbal and spatial abilities, as well as overall MA for WS participants (the only group with an intellectual disability) was obtained using the

Woodcock-Johnson Tests of Cognitive Ability – 3rd Edition (WJ-III COG; Woodcock, McGrew, & Mather, 2001) (see below for details). Measures of everyday executive functioning were obtained for the WS, ASD and SoAD groups using the Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Guy, Isquith, & Kenworthy, 1996), or the Behavior Rating Inventory of Executive Function, Adult Version (BRIEF-A; Roth, Isquith, & Gioia, 2005) (see below for details). The BRIEF and BRIEF-A were included in the present study to examine the relationship between everyday executive functioning processes and initial attention to the eyes within the clinical groups, and thus were only administered to the WS, ASD and SoAD samples. We had no reason to expect executive functioning difficulties in neurotypical individuals and so did not administer the BRIEF or BRIEF-A to controls. The Macquarie University Human Research Ethics Committee approved this study. Informed consent was obtained from the participants or their parents/caregivers, as appropriate.

Williams syndrome group. WS participants (7 male, 8 female) aged between 11.33 and 43.75 years (*M*=19.96*; SD*=8.06) were recruited through Williams Syndrome Australia Limited. All WS participants had a positive fluorescent in situ hybridisation (FISH) test showing deletion of the elastin gene at 7q11.23 (Fryssira et al., 1997). Exclusionary criteria for the WS group included a clinical diagnosis that was not related to the primary diagnosis of WS or a co-morbid neurological condition/insult. No participants met exclusionary criteria.

Autism spectrum disorder group. ASD participants (9 male, 6 female) aged between 11.00 and 42.50 years (*M*=25.98*; SD*=9.17) were recruited through Autism Spectrum Australia. All ASD participants received a formal clinical diagnosis of Autism Spectrum Disorder or Asperger syndrome from a clinical psychologist and/or paediatrician and met criteria for ASD according to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5; American Psychiatric Association, 2013), confirmed by

study authors MP or QW, qualified and registered psychologists. Further, ASD participants met clinical cut-offs for impairments in social reciprocity on the Social Responsiveness Scale-2nd Edition (SRS-2; Constantino & Gruber, 2012). For child ASD participants, the School-Age Form was completed by parents, while adult ASD participants completed the Adult Self-Report Form. Additionally, adult ASD participants completed the Ritvo Asperger and Autism Diagnostic Scale-Revised (RAADS-R; Ritvo et al., 2011), a self-report diagnostic measure designed for assisting in the diagnosis of ASD in adults with average intelligence. All participants scored above the diagnostic threshold of 65 on this measure, consistent with a diagnosis of ASD (Ritvo et al., 2011). Exclusionary criteria for the ASD group included a co-morbid neurological condition/insult or intellectual disability. No participants met exclusionary criteria.

Social anxiety disorder group. SoAD participants (1 male, 14 female) aged between 14.50 and 43.33 years (*M*=21.81*; SD*=6.91) were recruited through Macquarie University via advertisements placed around campus (*N*=8) and through the Centre for Emotional Health, a research and treatment clinic focused on the treatment and prevention of mental health problems including anxiety, located at Macquarie University (*N*=7). A diagnosis of SoAD was made using the Anxiety and Related Disorders Interview Schedule for DSM-5 (ADIS-5; Brown & Barlow, 2014) for adult participants or the parent and child versions of the Anxiety Disorders Interview Schedule for Children for DSM-IV (ADIS-C/P; Silverman & Albano, 1996) for child participants. All interviews were conducted by trained clinicians, including co-author QW. Diagnoses were rated on a severity scale from 0 to 8, with ratings of 4 or higher indicating symptoms are causing significant life interference. A principal diagnosis of SoAD was made for all participants, and the presence of other anxiety and mood disorders was allowed (13% of the SoAD group met criteria for an additional anxiety disorder and 53% met criteria for a mood disorder). For the SoAD group, exclusionary criteria included a neurodevelopmental disorder, such as

ASD, a co-morbid neurological condition/insult or intellectual disability. No participants met exclusionary criteria.

Chronological age control group. Neurotypical controls (6 male, 9 female) aged between 11.42 and 42.83 years (*M*=21.97*; SD*=7.98) were recruited through the Macquarie University Neuronauts Kids Science Club, a register of children and adolescents who elect to take part in research projects at Macquarie University and through the Macquarie University psychology participation pool, a register of undergraduate University students who participate in research in return for course credit. Participants were matched at a group level to the clinical groups on CA. For the CA-matched control group, exclusionary criteria included a prior neurological condition or insult, a history of developmental delay, intellectual disability (indexed by verbal or spatial ability scores ≤ 70), or a clinical diagnosis (e.g., a psychological condition, or cognitive or sensory impairment). No participant met exclusionary criteria.

Mental age control group. Neurotypical children (8 male, 7 female) aged between 6.33 and 11.08 years (*M*=8.43; *SD*=1.43) were recruited though the Macquarie University Neuronauts Kids Science Club. An average of MA equivalency across the subtests Verbal Comprehension and Spatial Relations from the WJ-III COG (Woodcock et al., 2001) was used to match neurotypical children to WS participants (see below for WJ-III subtest descriptions). For the MA-matched control group, exclusion criteria were the same as those used for the CA-matched control group. No participant met exclusionary criteria.

Measures and Procedure

Woodcock-Johnson Tests of Cognitive Ability – 3rd Edition (WJ-III COG; Woodcock et al., 2001). Estimates of verbal and non-verbal (spatial-perceptual) ability were obtained using the subtests Verbal Comprehension and Spatial Relations from the WJ-III COG (Woodcock et al., 2001). Verbal Comprehension requires participants to name objects, provide synonyms and antonyms for a range of words and complete verbal

analogies. Spatial Relations involves looking at shapes and determining from a selection of five options which pieces would join together to create the completed shape when oriented correctly. These subtests reliably measure comprehension-knowledge (*Gc*) and visual-spatial thinking (*Gv*), with median reliabilities of 0.97 and 0.86, respectively (Woodcock et al., 2001). Group performance on these subtests is summarised in Table 1.

Behavior Rating Inventory of Executive Function, Parent Form (BRIEF; Gioia, Guy, Isquith, and Kenworthy, 1996). The BRIEF is an 86-item questionnaire for parents of children aged 5 to 18 years, designed to measure different aspects of everyday executive function. Items map onto eight clinical scales: Inhibit, Shift, Emotional Control, Initiate, Working Memory, Plan/Organise, Organisation of Materials and Monitor. Two indices are computed from the clinical scales: Behavior Regulation Index and Metacognition Index; from which a single composite summary score is derived: the Global Executive Composite. The psychometric properties of the BRIEF are sound, with internal consistency alpha coefficients ranging from .80 to .98 (Gioia et al., 1996). See Appendix A for a description of the clinical scales that comprise the BRIEF. The BRIEF parent form was administered to parents or caregivers of individuals under 18 years in the WS, ASD and SoAD groups.

Behavior Rating Inventory of Executive Function – Adult Version, Self-Report and Informant Forms (BRIEF-A; Roth, Isquith, and Gioia, 2005). The BRIEF-A is a 75-item questionnaire designed to assess everyday executive functioning behaviours in adults aged 18 to 90 years. The BRIEF-A contains the same clinical scales as the BRIEF, with one additional scale (Self-Monitor[5]). The same indices and composite summary as those in the BRIEF can be derived from the clinical scales in the BRIEF-A. The reported internal consistency of the BRIEF-A is high, with alpha coefficients from .80 to .98 (Roth

[5] As Self-Monitor is not included as a clinical scale in the BRIEF, we have omitted this scale from further analyses.

et al., 2005). See Appendix B for a description of the clinical scales that comprise the BRIEF-A. The BRIEF-A informant form was administered to parents or caregivers of individuals 18 years and over in the WS group, as it is reported to be a more valid measure of executive functioning than the BRIEF in WS adults (Hocking et al., 2015). The BRIEF-A self-report form was administered to individuals 18 years and over in the ASD and SoAD groups.

BRIEF data. In line with Ng-Cordell et al. (2018), we combined data from the BRIEF and BRIEF-A; these data are referred to collectively as BRIEF data. For each clinical scale and index, T-scores can be derived, with higher scores corresponding to increased executive dysfunction. T-scores at or above 65 are suggestive of clinically significant impairments in executive functioning. As the number of items corresponding to each subscale differs between the BRIEF and BRIEF-A, we utilised T-scores, as opposed to raw scores, both for categorisation of our clinical samples and for analyses.

Biographical learning task. The current study employed a biographical face learning paradigm, originally developed by Charmet-Mougey et al. (2012) for use in neurotypical adults. This paradigm has since been modified for use with neurotypical children and individuals with WS (Boulton & Porter, 2017) and has also been used successfully with ASD and SoAD populations (Boulton et al., 2018a, 2018b, 2018d). Images from 24 different actors (12 male, 12 female), displaying neutral expressions were displayed to participants. Images were selected from the NimStim standardised face set and all identities selected were reliably identified as expressing neutral expressions by independent raters (Tottenham et al., 2009). The 24 faces were divided into three blocks. A fictional biographical vignette was presented with each block of faces, describing the individuals as: (1) *trustworthy characters*, where the faces were described as belonging to individuals who were trustworthy or ‘good’; (2) *neutral characters*, where the faces were described as belonging to individuals who were neutral or ‘neither good nor bad’ and (3)

untrustworthy characters, where the faces were described as belonging to individuals who were untrustworthy or 'bad'. Each block comprised four male and four female faces. The character types corresponding to each block were counterbalanced across participants to control for biases in responding. Counterbalancing was also employed to control for differences in perceived trustworthiness between faces.

To facilitate learning, separate training and testing phases were conducted. During the training phase, each block of faces was presented with a colour tint. LunaPic online picture editing software (www.lunapic.com) was used to tint each block blue, purple or orange. These colours were selected as they were considered to be relatively neutral and unlikely to be implicitly associated with emotionally salient information (Sutton & Altarriba, 2016; Takahashi & Kawabata, 2018). Colour tints were counterbalanced across conditions (blocks) and participants. Before each block of faces was presented, the corresponding biographical vignette (trustworthy characters, neutral characters, untrustworthy characters) was read aloud to the participant by the experimenter. Participants were instructed to look at each face until they believed they had memorised which character type it belonged to. Participants were able to look at the faces as many times as they liked and for as long as they liked. Once participants felt confident that they had memorised each face, the testing phase commenced. Each face was presented in greyscale and participants were asked to identify the character type of each face. Participants were provided with instant feedback after responding, and the eye-tracking experiment was not completed until participants were able to correctly label the character type of each face (when presented in greyscale) at an accuracy level of at least 80 percent. Participants were able to go back and look at the training stimuli (faces grouped by vignette type with colour tints) as often as they liked in order to help them remember the character type for each face. Once an accuracy level of at least 80 percent had been established for all participants, eye movements were recorded using the faces in greyscale.

Eye-tracking experiment. Eye-tracking data was collected as part of a larger study looking at social approach judgments and visual scanpaths (see Boulton, Porter & Wong, 2018c). Participants viewed the images on a Samsung 27-inch LED monitor from a distance of 60cm (viewing distance was controlled by seat position). The face images were 17.15cm (648 pixels) wide by 22.60cm (854 pixels) high, creating a horizontal visual angle of 16.27° and a vertical visual angle of 21.33°. Images were displayed in a pseudorandom order for each participant and were presented for 10 seconds. All images appeared in the centre of the computer screen.

An Eyelink-II gaze monitoring system (SR Research Ltd) was used to record eye movements, sampling at a temporal resolution of 500 Hz and a spatial resolution of 0.2°. An eye movement was classified as a saccade when its distance exceeded 0.2° and velocity reached 30°/s, or when its length exceeded 0.2° and its acceleration had reached 8,000°/s^2. Before the experiment began, a nine-point calibration of eye-fixation relative to the screen was conducted. Participants viewed a centrally placed black dot (10mm in diameter) with a white centre (2mm in diameter) that traversed eight locations around the centre and periphery of the screen. Participants were asked to fixate on the dot and follow it around the screen with their eyes. The dot did not move to a new location until the computer had recorded an adequate corneal 'lock' from the participant, which required at least 1,000ms viewing in each location. A successful calibration was achieved for all participants which indicated that a robust fixation recording could be obtained across the width and breadth of the computer monitor. The initial point of retinal attention during the task was controlled by a black cross presented on either the left or right of the screen for 2,000ms immediately prior to each face stimulus.

Before each image appeared on the screen participants were instructed to stare at a fixation cross, which appeared on either the left or right side of the screen, in a random order. This fixation cross was not positioned on any region of the face and ensured that all

participants were attending to the same part of the screen when the stimulus appeared. Each trial was initiated manually by the experimenter, with each face presented for 10,000ms seconds. Although previous studies have used shorter display times (e.g. 2,000ms or 5,000ms), a display time of 10,000ms was selected to allow for sufficient time to assess both attentional capture and attentional disengagement.

Defining areas of interest (AOIs). Regions of interest were drawn on each facial image using the manual drawing functions provided in the EyeLink Data Viewer software. Six facial AOIs were delineated including left eye, right eye, brow, nose, mouth and 'non-salient facial features' (in which an outline was drawn of the entire face, excluding the hair). As the present study was primarily interested in salient face regions and the eye region as a whole, we collapsed data over the eye, brow, nose and mouth regions ("salient facial features") and over the eye and brow regions ("eye region"). However, to ensure no lateralisation effects were present, between-group ANOVAs were conducted, comparing percentage of fixations and mean dwell time percentage to the left eye and right eye and no significant differences were found. Therefore, all analyses described used AOIs defined as (1) eye region; (2) salient facial features; and (3) non-salient facial features. Example AOIs are shown in Figure 1.

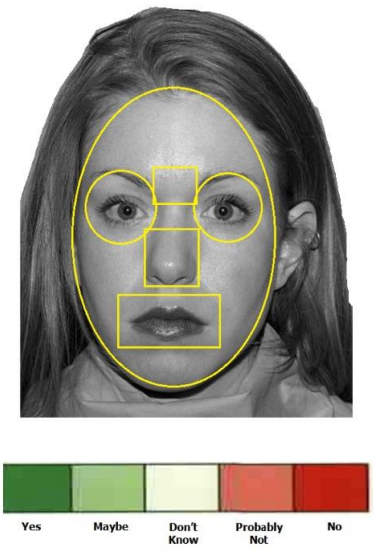


Figure 1. An example of the defined areas of interest.

Visual scanpath parameters. Visual scanpath parameters included: Mean Fixation percentage (the mean percentage of fixations made in each AOI), Mean Dwell Time Percent (the mean percentage of time spent fixating in each AOI), Mean Time to First Fixation (the mean length of time in milliseconds for the first fixation to a specified AOI) and Duration of First Fixations (the duration in milliseconds of first pass fixations in a specified AOI before a saccade was made out of the AOI). As in previous studies (Lewis et al., 2017; Porter et al., 2010), there were no differences in the results between Mean Fixation percentage and Mean Dwell Time percent, so only the latter is reported here.

In order to account for inter-individual variability in the time spent fixating on the face, and to focus our analysis on when participants were 'on-task' and looking at either the face or the approach scale presented beneath each face[6], we generated a Proportional Mean Dwell Time Percent to Salient Face Regions. This was defined as Mean Dwell Time Percent to Salient Face Regions divided by Mean Dwell Time Percent to whole face (including approach scale). The same calculation was employed to generate a Proportional Mean Dwell Time Percent to Non-Salient Face Regions. These variables were used for analyses investigating the differences in proportion of time spent looking at salient and non-salient facial regions across the whole viewing period. As ASD individuals have been found to spend less time looking at faces generally compared to neurotypical controls and WS individuals (Chita-Tegmark, 2016; Riby & Hancock, 2009a), we also looked at Absolute Mean Dwell Time Percent for salient and non-salient face regions. Looking solely at a relative measure may overestimate the amount of attention allocated to the eyes, particularly in a group such as ASD, where decreased face viewing has been noted. The pattern of results was identical for both Proportional and Absolute Mean Dwell Time

[6] While the current study did not investigate time spent looking at the approach scale, participants were required to look at this part of the image while eye-movements were recorded. As such, any time spent looking at this part of the image was considered 'on-task' viewing and was included in proportional dwell time calculations.

Percent; as a result we have only reported the results for Proportional Mean Dwell Time Percent.

Statistical Analysis

SPSS version 24 (IBM) was used to conduct all statistical analyses. One-way analyses of variance (ANOVAs) were used to explore group differences on continuous variables (e.g. CA and MA). Fisher's exact test was used to explore group differences on categorical variables (i.e., sex). Repeated measures ANOVAs were used to explore between- and within-group differences on the eye-tracking measures. With regards to follow-up analyses, we made an a priori decision to only compare the MA-matched control group to the WS group, given that the rationale for including the former group was to compare WS participants to MA-matched peers. Pearson's correlations were used to explore relationships between visual scanpaths and executive functioning in the clinical groups. As a result of the small sample size, and in an effort to minimise the likelihood of a Type-II error, corrections for multiple comparisons were not applied and alpha was set to 0.05 for all following analyses (see Rothman, 1990). For any critical values at or approaching an alpha level of 0.05, moderate to large effect sizes would minimise the likelihood of a Type-I error. As such, and to aid in the interpretation of analyses, effect sizes are reported throughout the results (for *d*: 0.2 = small effect size, 0.5 = medium effect size, 0.8 = large effect size; for *r*: 0.1 = small effect size, 0.3 = medium effect size, 0.5 = large effect size according to Cohen, 1988).

Results

Table 1 shows demographic information for each group. No statistically significant differences in CA were observed between the WS, ASD, SoAD and CA -matched control groups (p=.229). Likewise, no statistically significant difference in MA was observed between the WS and MA control groups (p=.897). Sex differences were observed between groups due to the SoAD group being predominantly composed of females (p=.020). Higher

prevalence rates of SoAD, as well as elevated clinical severity of the disorder in women have recently been reported (Asher et al., 2017), which may explain the increased proportion of females in this sample. Excluding the SoAD participants, there were no significant group differences in sex (p=.823).

Group differences in verbal ability were observed; standard scores in the ASD, SoAD, CA- and MA-matched comparison groups were significantly higher than those in the WS group (all p-values <.001). Similarly, group differences in spatial ability were observed; standard scores in the ASD group were significantly higher than those in the SoAD and CA-matched control groups (all p-values <.004) while standard scores in the ASD, SoAD, CA-matched and MA-matched comparison groups were significantly higher than those in the WS group (all p-values <.001). Given the group differences in verbal and spatial ability, we assessed whether these variables were related to our dependent variables of interest, namely, proportional mean dwell time to salient or non-salient face regions, attentional capture by the eye region, or attentional disengagement from the eye region. Verbal ability correlated significantly with proportional mean dwell time to salient face regions in the MA-matched control group only (r=–.57, p=.026), while spatial ability was not related to proportional dwell time to salient or non-salient face regions, attentional capture by the eye region, or attentional disengagement from the eye region within any group (all p-values >.073). Whilst a standard approach in instances of between-group differences in cognitive ability is to control for cognitive ability statistically, this can increase the likelihood of Type-II error. Additionally, the suitability of including cognitive ability as a covariate when the relationship between cognitive ability and the dependent variable(s) of interest differs across groups has been brought into question (for a broader discussion see Dennis et al., 2009 and Miller & Chapman, 2001). Given that much of the literature covaries for cognitive ability in instances such as ours (although, see Jarivinen, Ng & Bellugi, 2015 and Jarvinen et al., 2015 for recent exceptions), we conducted all

analyses with and without verbal and spatial ability included as covariates and found that the pattern of results did not differ. Thus, we report the results of the simple models without covariates. This methodology also aligns with that recently employed by Chevallier et al. (2015) in ASD individuals.

Table 1

Demographic characteristics for each group.

	CA in years	MA in years	Sex (n, % Female)	Verbal Ability	Spatial Ability
CA (*n*=15)	21.97 (7.98)	–	9 (60%)	99.67 (7.85)	101.67 (6.35)
ASD (*n*=15)	25.98 (9.17)	–	6 (40%)	107.00 (11.95)	110.27 (9.07)
SoAD (*n*=15)	21.81 (6.91)	–	14 (93%)	102.93 (8.05)	100.40 (8.14)
WS (*n*=15)	19.96 (8.06)	7.72 (2.05)	8 (53%)	69.07 (10.25)	76.71 (9.14)
MA (*n*=15)	8.43 (1.43)	7.81 (1.74)	7 (47%)	105.77 (9.78)	99.15 (8.49)

Note: CA = Chronological age-matched controls; ASD = Autism Spectrum Disorder; SoAD = Social Anxiety Disorder; WS = Williams syndrome; MA = mental age-matched controls. Verbal and spatial ability are reported using standard scores (*M*=100; *SD*=15 on a standardised population). Data expressed as mean (SD).

Visual Attention to Salient and Non-Salient Facial Features

The proportion of time spent looking at salient and non-salient facial features for each group is presented in Table 2. To investigate whether groups differed in the proportion of time they spent looking at salient and non-salient facial features, we used a repeated measures ANOVA with Group as the between-subjects factor and Biographical Information (trustworthy, neutral, untrustworthy) and Facial Feature (salient, non-salient) as within-subjects factors. Results revealed significant main effects for Facial Feature, $F(1,70)=14.57$, $p<.001$, partial $\eta^2=.17$, and Group, $F(4,70)=12.62$, $p<.001$, partial $\eta^2=.42$. The main effect of Biographical Information was marginally significant, $F(2,140)=3.01$, $p=.052$, partial $\eta^2=.04$. We also observed a significant Group by Facial Feature interaction, $F(4,70)=6.78$, $p<.001$, partial $\eta^2=.28$. No other interactions reached statistical significance (p-values >.059). The marginally significant main effect of biographical information was

driven by all participants, irrespective of group, spending significantly more time looking at non-salient features of faces that had been associated with untrustworthy biographical information (*M*=40.1; *SD*=10.6), relative to non-salient features of faces that had been associated with neutral biographical information (*M*=37.3; *SD*=10.5), *t*(70)=2.91, *p*=.005, *d*=0.27.

Table 2

Proportional Mean Dwell Time Percent to salient and non-salient facial features by group and biographical information

	ASD	SoAD	WS	CA Controls	MA Controls
Trustworthy Characters					
Salient	51.4 (10.5)	49.3 (17.3)	50.4 (12.7)	50.8 (10.6)	29.9 (9.0)
Non-salient	38.0 (8.1)	41.3 (14.7)	33.6 (8.9)	41.5 (8.9)	40.3 (9.5)
Other[a]	10.6 (5.6)	9.4 (7.9)	16.0 (13.8)	7.7 (6.8)	29.7 (12.5)
Neutral Characters					
Salient	53.9 (12.3)	51.5 (16.5)	48.5 (14.2)	49.5 (11.8)	29.7 (6.8)
Non-salient	35.9 (5.7)	36.9 (13.6)	32.4 (8.2)	39.3 (9.2)	41.8 (12.7)
Other[a]	10.2 (8.3)	11.6 (7.7)	19.1 (14.8)	11.2 (10.4)	28.5 (12.2)
Untrustworthy Characters					
Salient	52.1 (14.3)	56.5 (15.0)	44.4 (11.3)	48.2 (9.9)	30.0 (6.6)
Non-salient	38.7 (11.2)	35.1 (13.2)	38.2 (9.1)	43.5 (9.7)	45.3 (6.4)
Other[a]	9.2 (5.3)	8.4 (6.7)	17.5 (14.2)	8.3 (8.3)	24.7 (9.2)
All Characters					
Salient	52.5 (11.2)[f]	52.6 (14.9)[f]	47.9 (10.0)[b,f]	49.6 (10.2)	29.9 (3.7)[b,e]
Non-salient	37.5 (6.6)[f]	37.7 (12.7)[f]	34.7 (6.8)[c,d,f]	41.4 (8.2) [d]	42.4 (7.2)[c,e]
Other[a]	10.0 (5.3)	9.7 (6.6)	17.4 (12.9)	9.0 (8.1)	27.7 (8.3)

Note: CA = Chronological age-matched controls; ASD = Autism Spectrum Disorder; SoAD = Social Anxiety Disorder; WS = Williams syndrome; MA = mental age-matched controls. Data expressed as mean (SD). [a]Other features refers to proportion of time spent looking at the approach scale included on the screen; [b]Williams syndrome > Mental age-matched controls; [c]Mental age-matched controls > Williams syndrome; [d]Chronological age-matched controls > Williams syndrome; [e]Non-salient facial features > Salient facial features; [f]Salient facial features > Non-Salient facial features. All *p*-values <.05.

To decompose the Group by Facial Feature interaction, we looked separately at between- and within-group differences in the proportion of time spent looking at salient and non-salient facial features, independent of the biographical information the faces were

associated with. Considering first between-group differences, follow up analyses revealed that, compared to MA-matched controls, WS participants spent significantly more time looking at salient facial features, $t(70)=4.62$, $p<.001$, $d=2.38$, and significantly less time looking at non-salient facial features, $t(70)=–2.48$, $p=.017$, $d=1.10$. Further, WS participants spent significantly less time looking at non-salient facial features when compared to CA-matched controls, $t(70)=2.16$, $p=.036$, $d=0.89$. No other between-group comparisons reached statistical significance.

Within-group differences are illustrated in Figure 2. Looking at within-group differences in the proportion of time spent looking at salient versus non-salient facial features, MA-matched control participants spent significantly less time looking at salient facial features relative to non-salient facial features, $t(70)=–2.78$, $p=.007$, $d=1.59$. The opposite pattern was observed in the clinical groups, with significantly larger proportions of time spent looking at salient (relative to non-salient) facial features observed in the WS ($t(70)=3.29$, $p=.001$, $d=1.00$), ASD ($t(70)=3.33$, $p=.001$, $d=0.68$), and SoAD ($t(70)=2.93$, $p=.004$, $d=0.51$) groups. CA-matched controls did not differ in the proportion of time spent looking at salient versus non-salient facial features.

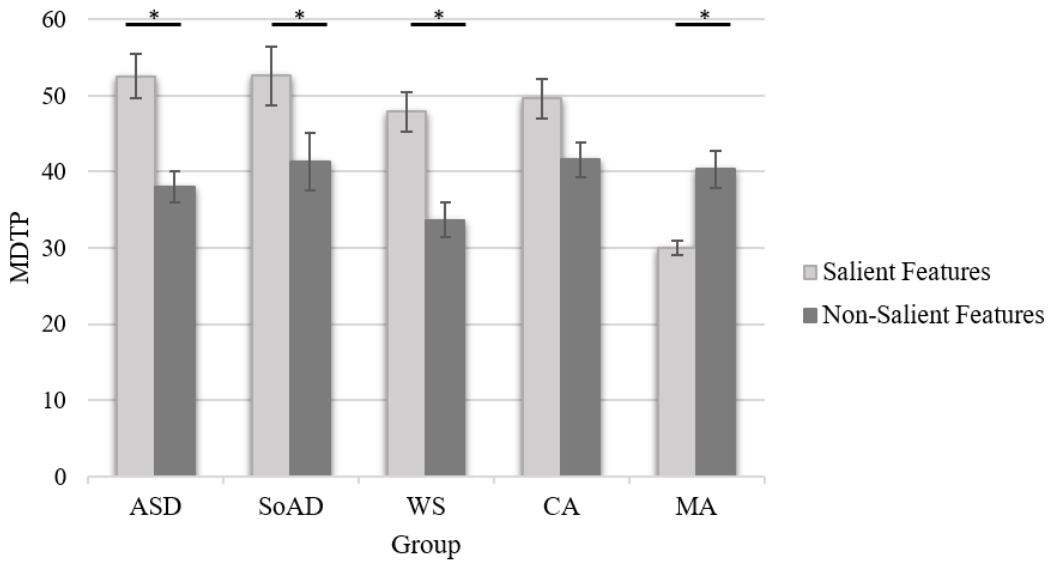


Figure 2. Mean dwell time percentage on salient versus non-salient features for all faces across groups. Error bars represent standard error. *indicates $p<0.05$

Visual Attention to the Eye Region: Attentional Capture

The mean times to first fixation in the eye region for the clinical and control groups are presented in Table 3. An ANOVA with Group as the between-subjects factor and Biographical Information as the within-subjects factor (trustworthy, neutral, untrustworthy) was conducted to examine group differences in the mean time to first fixation in the eye region (in milliseconds). Results revealed that neither the main effect of Biographical Information, $F(2,140)=1.12$, $p=.331$, partial $\eta^2=.02$, nor the interaction of Group by Biographical Information, $F(8,140)=1.17$, $p=.323$, partial $\eta^2=.06$ were statistically significant, however there was a significant main effect of Group, $F(4,70)=3.74$, $p=.008$, partial $\eta^2=.18$. Follow-up comparisons demonstrated that, compared to the CA-matched control group, the mean time to first fixation in the eye region was significantly faster in the SoAD group $t(70)=-2.80$, $p=.048$, $d=0.92$. No other pairwise comparisons reached statistical significance. In other words, compared to CA-matched controls, the eye region of faces captured the attention of SoAD participants significantly earlier in the viewing session, irrespective of the biographical information associated with the face.

Table 3

Mean time (in milliseconds) to first fixation in the eye region.

	ASD	SoAD	WS	CA Controls	MA Controls
Trustworthy Characters	1485	1440	1932	2001	1358
	(668)	(714)	(592)	(499)	(541)
Neutral Characters	1468	1523	1424	1949	1319
	(644)	(599)	(545)	(669)	(611)
Untrustworthy Characters	1678	1533	1580	1954	1396
	(581)	(486)	(488)	(701)	(591)
All Characters	1544	1499[a]	1645	1968[a]	1357
	(497)	(505)	(390)	(516)	(362)

Note: ASD = Autism Spectrum Disorder; SoAD = Social Anxiety Disorder; WS = Williams syndrome; CA = Chronological age-matched controls; MA = mental age-matched controls. Data expressed as mean (SD).
[a]Social Anxiety Disorder < Chronological age-matched controls ($p<.05$).

Visual Attention to the Eye Region: Attentional Disengagement

Table 4 shows the mean durations of first pass fixations in the eye region (before a saccade was made to another region) for the clinical and control groups. An ANOVA with Group as the between-subjects factor and Biographical Information as the within-subjects factor (trustworthy, neutral, untrustworthy) was conducted to examine group differences in the duration of the first pass fixations in the eye region before a saccade was made away from this region (in milliseconds). Results revealed that the main effect of Biographical Information did not reach statistical significance, $F(2,140)=0.51$, $p=.603$, partial $\eta^2=.01$, however, we observed a significant main effect of Group, $F(1,70)=4.33$, $p=.003$, partial $\eta^2=.20$, as well as a significant Group by Biographical Information interaction $F(8,140)=2.93$, $p=.005$, partial $\eta^2=.14$. To further explore this interaction, we looked separately at between- and within-group differences in the mean duration of first pass fixations in the eye region for faces paired with trustworthy, neutral or untrustworthy biographical information.

Considering between-group differences in the duration of first pass fixations in the eye region, follow-up comparisons revealed that, compared to MA-matched controls, WS participants displayed significantly longer first fixations in the eye region when looking at faces, irrespective of the biographical information the face had been associated with (all *p*-values <.029). Further, in comparison to ASD individuals, those with WS displayed significantly longer first fixations in the eye region when looking at faces that had been paired with trustworthy biographical information, $t(70)=2.64$, $p=.010$, $d=0.76$. No other between-group comparisons reached statistical significance.

When looking at within-group differences in the duration of first pass fixations in the eye region, our results suggest that, for WS individuals, the first fixation in the eye region was significantly longer when the face was associated with trustworthy biographical information compared to when it was associated with either neutral, $t(70)=2.01$, $p=.048$,

d=0.35 or untrustworthy biographical information, *t*(70)=3.68, *p*<.001, *d*=0.63. No other within-group comparisons reached statistical significance. Between-group differences are displayed in Table 4; within-group differences are illustrated in Figure 3.

Table 4

Mean duration of first fixations (in milliseconds) in the eye region.

	ASD	SoAD	WS	CA Controls	MA Controls
Trustworthy Characters	645[b]	737	923[b]	822	494
	(240)	(306)	(455)	(188)	(151)
Neutral Characters	748	721	806	745	492
	(319)	(283)	(375)	(182)	(177)
Untrustworthy Characters	746	814	686	760	496
	(251)	(281)	(269)	(145)	(192)
All Characters	713	758	805[a]	776	494[a]
	(330)	(268)	(330)	(118)	(120)

Note: ASD = Autism Spectrum Disorder; SoAD = Social Anxiety Disorder; WS = Williams syndrome; CA = Chronological age-matched controls; MA = mental age-matched controls. Data expressed as mean (SD). [a]Williams syndrome > Mental age-matched controls; [b]Williams syndrome > Autism Spectrum Disorder (all *p*-values <.029).

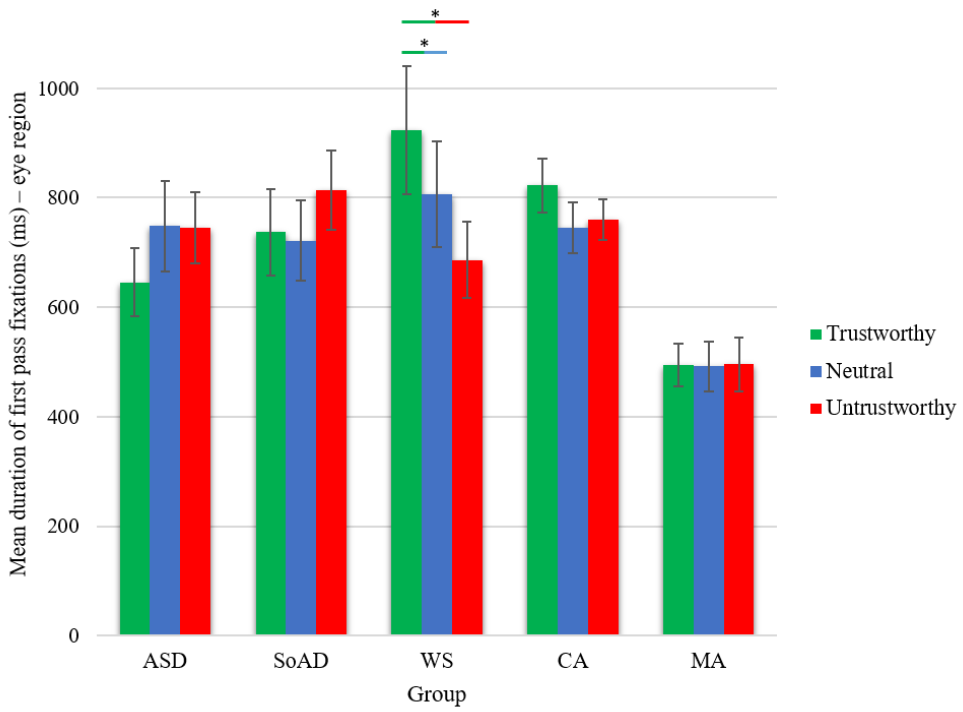


Figure 3. Average duration of first pass fixations in the eye region. Error bars represent standard error. * indicates $p < 0.05$

Relations between Attentional Capture, Disengagement and Executive Functioning

Figures 4 and 5 illustrate the number of participants with WS, ASD and SoAD, respectively, with T-scores falling within the normal or clinically elevated ranges on the Clinical scales of the BRIEF, as well as the Behavior Regulation and Metacognitive Indices and the Global Executive Composite. Of note, BRIEF data was not available for one ASD participant and three WS participants. In order to investigate how initial attention towards the eye region may be linked to executive functioning in the ASD, SoAD and WS groups, Pearson correlations were applied. Caution is required when interpreting these results due to the small sample size. Visual inspection of the scatterplots for each significant correlation revealed no evidence of outliers.

Associations between attentional capture and executive functioning. For SoAD individuals, slower initial fixations to the eye region of faces that had been paired with untrustworthy biographical information were significantly and positively correlated with T-scores on the Shift ($r(15)=.54$, $p=.040$), and Plan/Organise ($r(15)=.54$; $p=.036$), scales of the BRIEF, as well as the Global Executive Composite ($r(15)=.52$, $p=.049$). For individuals with WS, faster initial fixations to the eye regions of faces (regardless of biographical information) were significantly and negatively correlated with T-scores on the Inhibit ($r(12)=–.66$, $p=.019$), Emotional Control ($r(12)=–.68$, $p=.016$), Initiate ($r(12)=–.69$, $p=.014$), and Plan/Organise ($r(12)=–.73$, $p=.008$) scales, as well as the Behavioral Regulation Index ($r(12)=–.68$, $p=.015$), Metacognitive Index ($r(12)=–.67$, $p=.018$), and Global Executive Composite ($r(12)=–.69$, $p=.013$), of the BRIEF. All other correlations failed to reach statistical significance.

Associations between attentional disengagement and executive functioning. For ASD individuals, faster disengagement from the eye region of all faces, regardless of biographical information, was significantly and negatively correlated with T-scores on the

Emotional Control scale ($r(14)=–.84$, $p<.001$), as well as the Behavioral Regulation Index ($r(14)=–.77$, $p=.001$) of the BRIEF. For individuals with WS, disengagement from the eye region of faces that had been paired with untrustworthy biographical information was significantly and negatively correlated with T-scores on the Shift ($r(12)=–.66$, $p=.019$), Initiate ($r(12)=–.59$, $p=.041$), and Plan/Organise ($r(12)=–.87$, $p<.001$) scales, as well as the Behavioral Regulation Index ($r(12)=–.61$, $p=.036$), Metacognitive Index ($r(12)=–.64$, $p=.024$), and Global Executive Composite ($r(12)=–.63$, $p=.028$), of the BRIEF. All other correlations failed to reach statistical significance.

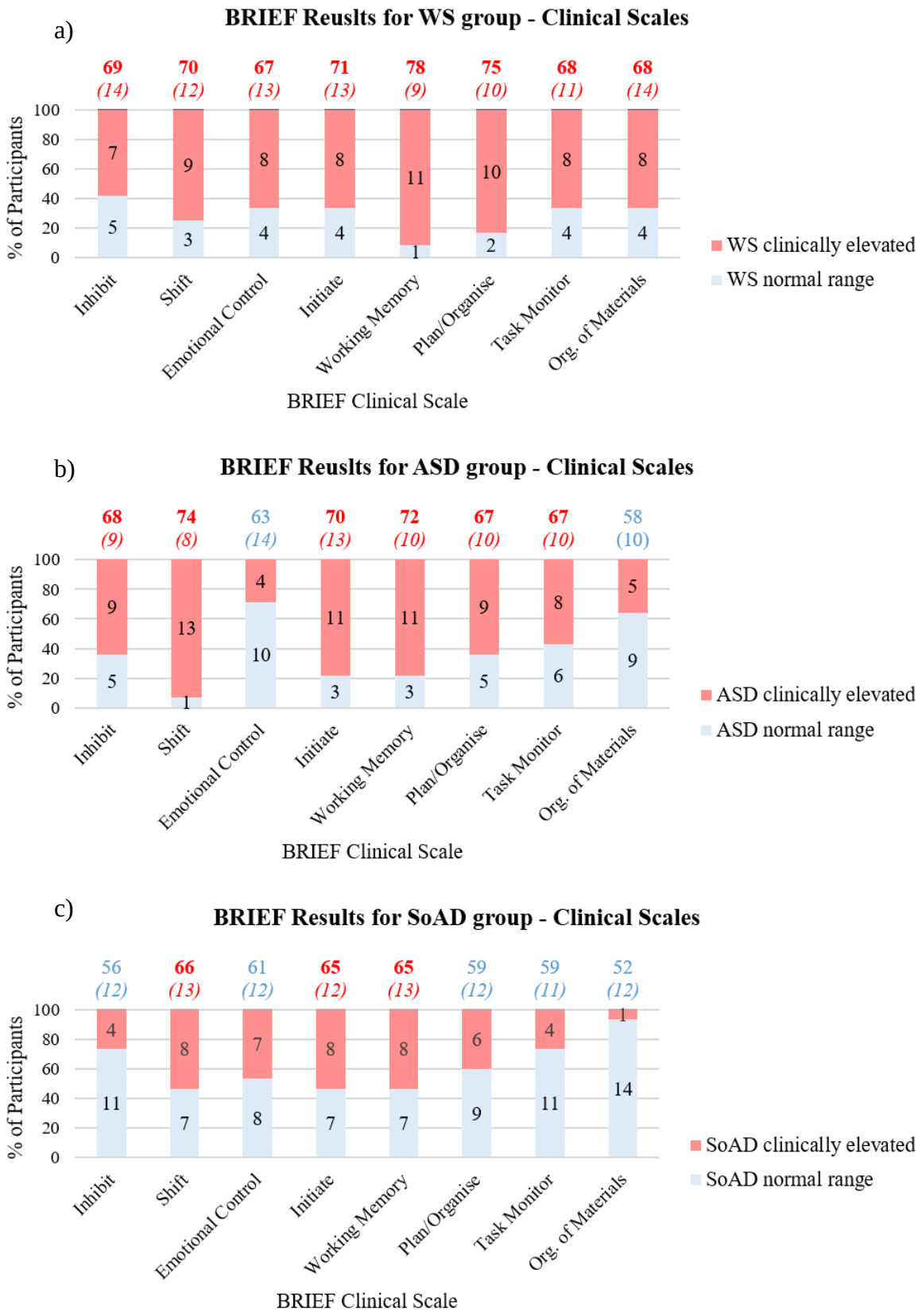
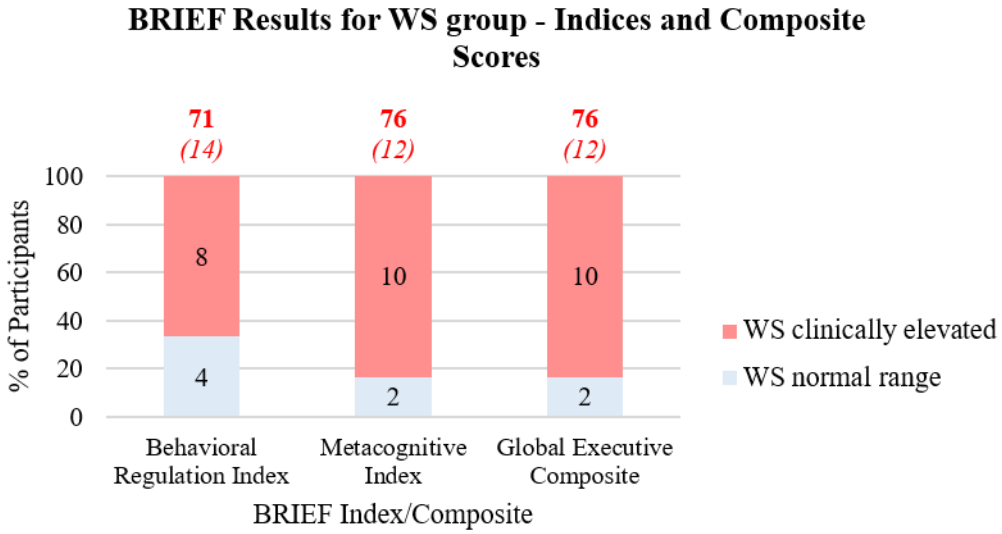
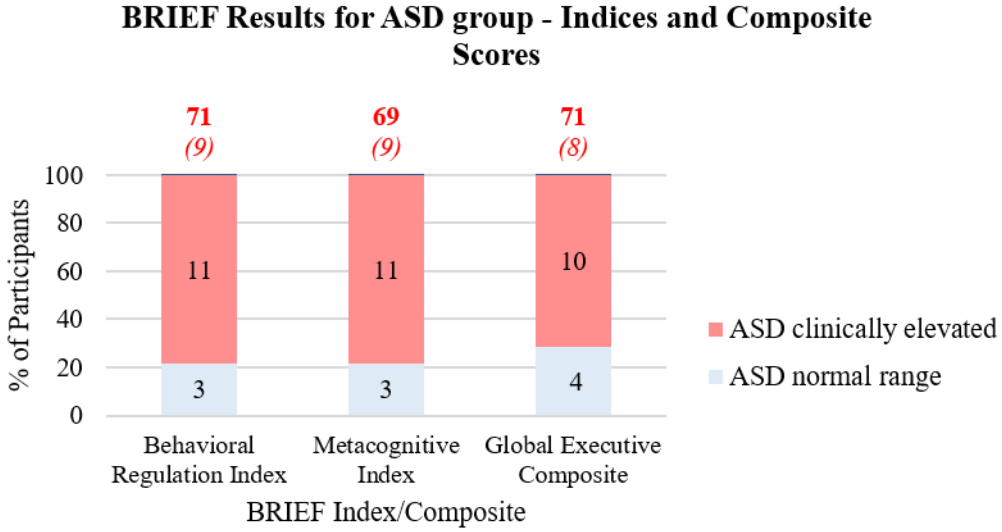


Figure 4. Percentage of participants in the WS, ASD and SoAD groups falling into the clinically elevated and normal ranges on the BRIEF Clinical Scales (number of participants indicated). T-scores (Mean; *SD*) are indicated above scales; T-scores 65 and higher suggest clinically significant impairments.

a)



b)



c)

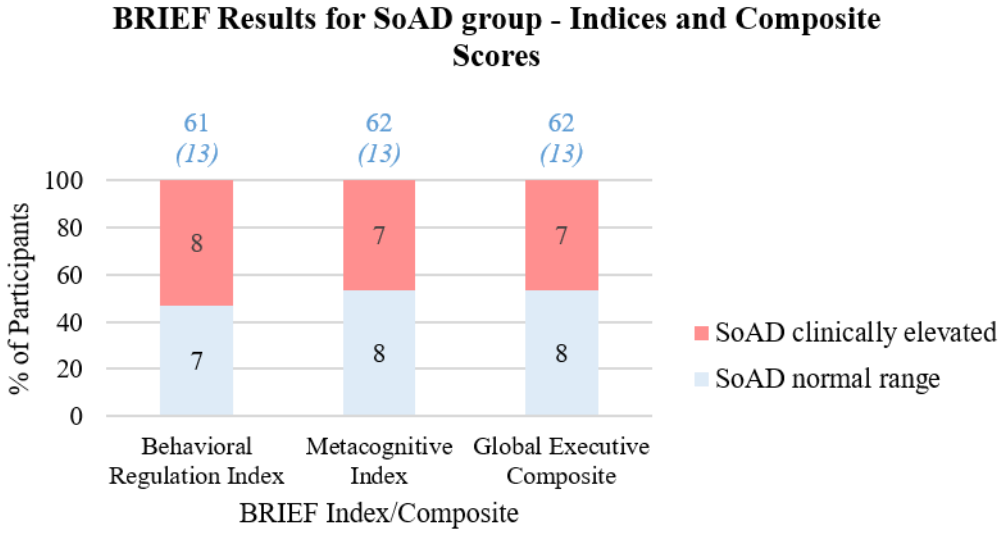


Figure 5. Percentage of participants in the WS, ASD and SoAD groups falling into the clinically elevated and normal ranges on the BRIEF Indices and Composite Scores (number of participants indicated). T-scores (Mean; *SD*) are indicated above scales; T-scores 65 and higher suggest clinically significant impairments.

Discussion

The primary goal of the current study was to examine visual attention to faces in individuals with WS, ASD or SoAD, as well as neurotypical controls. As a novel manipulation, we utilised faces that were associated with trustworthy, neutral or untrustworthy biographical information. We were interested in group differences in time spent looking at salient (eyes, nose and mouth) and non-salient (forehead, temples, cheeks, jaw and chin) facial features, as well as any group differences in attentional capture or attentional disengagement of the eye region. Further, we explored how attentional capture and attentional disengagement patterns were associated with executive functioning capabilities in WS, ASD and SoAD individuals.

Findings indicated that WS individuals spent significantly more time looking at salient facial features compared to neurotypical MA-matched controls, irrespective of whether the face had been paired with trustworthy or untrustworthy biographical information. However, the WS group did not differ from the ASD, SoAD or CA-matched control groups in time spent looking at salient face features, suggesting that face scanpaths in WS individuals, at least for the task employed here, were more sophisticated than what would be expected by their developmental level, and more closely resembled those seen in CA-matched individuals. Further, WS individuals spent significantly less time exploring non-salient face features compared to both CA- and MA-matched controls[7]. Taken together, these findings are consistent with Porter et al. (2010), who also found that WS individuals spent significantly more time looking at salient face features compared to MA-matched controls, regardless of whether happy, neutral or angry expressions were shown. Moreover, our findings revealed the WS, ASD and SoAD groups spent more time looking at salient features, as opposed to non-salient features, across all faces. While CA controls

[7] It should be noted that viewing time was not solely comprised of time spent looking at salient and non-salient face regions; participants also looked at an approach scale (results not reported in this paper).

did not differ in time spent looking at salient versus non-salient face features, MA controls displayed the opposite pattern to the clinical groups, spending longer exploring non-salient features compared to salient features across all faces. In contrast to our prediction, SoAD individuals did not spend less time looking at salient features of faces that had been paired with untrustworthy biographical information, indicating that visual attention patterns for faces paired with threatening biographical information may deviate from those reported for faces paired with threatening emotional information in this group (for instance, salient features of angry faces are commonly avoided, see Chen and Clark, 2017 for a recent review). Moreover, whilst we anticipated that ASD individuals would spend less time looking at salient compared to non-salient face features, this was not the case. A possible explanation for this finding may lie in the task demands. Participants were required to make an approach judgment when viewing each face, which likely contributed to ASD individuals spending more time looking at salient features in order to recall the biographical information that had been paired with each face and make an appropriate approach judgment[8].

Whilst our findings indicate that biographical information did not influence the amount of time spent looking at salient versus non-salient face features, these results suggest that biographical information may influence initial visual attention to the eye region of faces. As predicted, the eye region of faces did not capture the attention of WS individuals, however, compared to MA-matched controls, individuals with WS did spend more time looking at the eye region of all faces once an initial fixation was made, indicative of attentional disengagement difficulties. Additionally, the WS and ASD groups differed in the time taken to disengage their attention from the eye region of faces, specifically those paired with trustworthy information, such that WS individuals took

[8] Results from the approach judgment task are reported in (Boulton et al., 2018d).

longer to disengage their attention from the eye region of those faces, relative to ASD individuals. In line with earlier cross disorder comparisons (e.g., see Riby & Hancock, 2009a), these findings suggest that both WS and ASD individuals display atypicalities in attentional disengagement from the eye region of faces, which may correspond to the divergent social profiles seen in these conditions. Moreover, within the WS group alone, previously learnt biographical information appeared to influence attentional disengagement patterns, with WS individuals taking significantly longer to disengage their attention from the eye region of faces that had been paired with trustworthy biographical information, compared to faces that had been paired with either neutral or untrustworthy biographical information. These findings are consistent with prior research and the suggestion that difficulties disengaging attention from faces may at least partially underlie some of the unusual social behaviours seen in WS (Porter et al., 2010; Riby et al., 2011).

Considering our attentional disengagement results in the context of broader research investigating the WS social phenotype, there is evidence that WS individuals display attentional biases to happy emotional expressions (Dodd & Porter, 2010; Goldman et al., 2016) and make fewer negative attributions when presented with ambiguous social scenarios (Godbee & Porter, 2013), suggesting that a positive social bias may be a key feature of social behaviour in this disorder. This also parallels findings at a neurological level, which show heightened activity of the amygdala for happy faces (Haas et al., 2009). Our results are consistent with this assertion, with WS individuals displaying particular attentional disengagement difficulties from the eye region of faces that were paired with positive information, as opposed to those that were paired with neutral or threatening information. This study was the first to demonstrate that this positive bias may be related to attentional disengagement difficulties using biographical as opposed to emotional facial stimuli.

As predicted, the eye region of faces captured the attention of SoAD individuals

significantly more relative to neurotypical controls, irrespective of the biographical information associated with the face. Consistent with recent findings from Boll et al. (2016), this may reflect an increased vigilance for potential threat and may be a contributing factor to the avoidance of social situations seen in SoAD individuals. However, our findings did not reveal slower disengagement from the eye region of faces in the SoAD group compared to neurotypical controls. While theoretical models of SoAD suggest that difficulties disengaging attention from signals of potential threat, such as faces, contribute to the maintenance of anxiety and avoidance behaviours in SoAD (e.g. see Rapee & Heimberg, 1997), it is possible that these difficulties are more likely to occur in everyday social scenarios where the likelihood of a social interaction is high, as opposed to viewing static faces on a computer, an arguably less threatening environment.

While we anticipated that ASD individuals would display faster attentional disengagement from the eye region of faces in comparison to both the SoAD and neurotypical control groups, in line with the eye avoidance hypothesis (Tanaka & Sung, 2016), no differences in attentional disengagement were observed. While social interactions and direct eye contact can be a source of discomfort for ASD individuals (Trevisan et al., 2017), it is possible that the experimental task used in the current study did not elicit the same degree of discomfort and, thus, did not prompt the eye avoidance that one may expect to see during day to day social interactions. Nevertheless, eye avoidance in ASD has been demonstrated using experimental paradigms, with ASD individuals looking away from the eye region of static face stimuli more rapidly than neurotypical controls (Kliemann et al., 2010), as well as displaying elevated amygdala reactivity when looking at the eye region of faces (Kliemann et al., 2012). Finally, our results did not reveal any differences between WS and SoAD individuals in terms of attentional capture or attentional disengagement. Whilst these findings suggest that attention patterns for faces do not seem to differ significantly between individuals with WS or SoAD, further

comparisons between these groups are warranted, given their opposing social profiles and given that this was the first study to compare visual attention to faces in WS and SoAD.

To the best of our knowledge, this is the first study to research has yet to directly compare executive functioning capabilities across WS, ASD and SoAD. Our findings revealed that fifty percent of each clinical group demonstrated clinically elevated scores on the BRIEF scales of Shift, Initiate and Working Memory, alongside clinically elevated scores on the Behavioural Regulation Index. Difficulties in other executive functioning domains, such as Inhibition and Emotional Control, seemed to be more diverse across conditions. These findings tentatively suggest that executive functioning impairments are common in WS, ASD and SoAD.

Given the importance of executive functions in both attention and voluntary eye movements (Sereno et al., 2009), we explored the relationship between everyday executive functioning processes and initial attention patterns to the eye region of faces, namely attentional capture and attentional disengagement. An interesting pattern of results was revealed. Executive functioning capabilities were: significantly and negatively associated with both attentional capture and attentional disengagement in WS individuals; significantly and positively associated only with attentional capture in SoAD individuals and significantly and negatively associated with only attentional disengagement in ASD individuals. Although we did not have any specific hypotheses due to the exploratory and preliminary nature of these analyses, specific findings of interest in the context of extant research are highlighted below.

Disinhibition was associated with attentional capture to the eye region of faces in the WS group. It has been proposed that the eye region of faces is particularly salient for WS individuals (e.g. see Porter et al., 2010), which, when coupled with increased disinhibition, may make it difficult for these individuals to avoid looking straight at the eyes during social interactions. The current finding also aligns with Little et al. (2013) and

Porter et al. (2007), where deficits in response inhibition were significantly related to increased social approach behaviour in WS, providing further evidence that deficits in executive functioning may be critically related to the WS social phenotype.

Higher scores on the Behaviour Regulation Index were associated with faster attentional disengagement in both WS and ASD individuals. Scattered and reduced general attention is commonly seen in individuals with executive functioning difficulties (Miyake & Friedman, 2012), which may explain this finding. Notably, while this finding was observed for all faces in ASD individuals, it was only observed for faces paired with untrustworthy biographical information in WS individuals, suggesting that biographical information may influence the interplay between executive functioning and attention for faces in WS individuals, such that faces paired with threatening (untrustworthy) information are initially attended to for less time when behaviour regulation difficulties are present. This result also aligns with the above finding, where WS individuals displayed difficulties disengaging their attention from faces paired with trustworthy information, further suggesting that positive faces may be more salient than threatening faces for this group. Moreover, previous neuroimaging research may help to explain these findings; given evidence which suggests that WS individuals display decreased amygdala reactivity to threatening faces (Haas et al., 2009; Meyer-Lindenberg et al., 2005), it is possible that executive functioning difficulties may contribute to decreased attention for threatening faces in WS individuals.

For individuals with SoAD, we observed that increased difficulties in shifting, also known as cognitive flexibility, were related to slower initial fixations to the eye regions of faces paired with untrustworthy biographical information. Interestingly, while previous literature suggests that compromised executive functioning is related to increased symptom severity in SoAD individuals (e.g. see Fujii et al., 2013), we did not find evidence of such a

relationship[9]. A consideration of how executive functioning was measured between studies may help to explain this apparent inconsistency. Whilst Fujii et al. (2013) used performance-based tests to assess executive functioning, we utilised a questionnaire-based measure of everyday executive functioning. While speculative given the lack of executive functioning research in SoAD, it is possible that results from performance-based tests may not necessarily correspond to everyday executive functioning capabilities in SoAD, as has been found in the neurodevelopmental literature (e.g., see Kenworthy, Yerys, Anthony and Wallace (2008) for a discussion of this issue in ASD individuals).

Strengths, Limitations and Future Directions

It is rare to find studies that directly compare neurodevelopmental and anxiety disorders. Such studies add value to the literature, providing insight into social-behavioural features that are either shared, contrasting or uncommon across disorders. To the best of our knowledge, this is the first study to directly compare visual attention to faces across individuals with WS, ASD or SoAD. Further, while previous research examining visual attention to faces has largely used faces displaying simple emotional expressions (e.g., see Chen & Clarke, 2017; Papagiannopoulou et al., 2014; Porter et al., 2010) or more complex mental states (e.g., see Hanley, McPhillips, Mulhern, & Riby, 2013; Hanley, Riby, Caswell, Rooney, & Back, 2013), the current study employed a novel biographical paradigm, allowing us to explore the effect of salient biographical information on visual attention in individuals with these disorders.

Despite these unique contributions, there are several limitations of the current study which should be acknowledged. Whilst comparable to recent studies (Goldman et al., 2016; Hirai et al., 2017), as well as previous cross-disorder comparisons between WS and ASD (Jarvinen et al., 2015; Riby & Hancock, 2009b), our sample size was small.

[9] SoAD symptom severity was measured using the short form Social Interaction Anxiety and Social Phobia Scale (SPS-6 and SIAS-6; Peters et al., 2012). SoAD symptom severity data is available upon request.

Additionally, our participants were not matched on sex in the current study due to the increased prevalence of SoAD in females (Asher et al., 2017), however, all groups were matched on chronological age, and our WS group was also compared to a MA-matched control group, consistent with much of the WS literature (Hanley et al., 2013; Hirai et al., 2016; Porter et al., 2010). Further, the majority of our results revealed moderate to large effect sizes, highlighting the clinical significance of these findings. It should also be noted that the present study utilised self-report measures to assess everyday executive functioning in adults with ASD or SoAD. It is possible that these individuals, particularly those with ASD, may lack insight into their executive functioning deficits (e.g., see Frith & Happé, 1999), thus, future research may benefit from comparing informant- and self-report measures of executive functioning in these groups, as well as possibly using performance based measures of executive functioning, although here are arguments that face-to-face measures lack ecological validity (Isquith, Roth, & Gioia, 2013).

Given the novelty of the biographical learning task used in this study, as well as the relative lack of cross-disorder comparisons between WS, ASD and SoAD, future research would benefit from building on these preliminary findings. In particular, future studies should utilise neuroimaging to explore amygdala responsivity to faces paired with trustworthy or untrustworthy biographical information. Given the amygdala anomalies previously reported across WS, ASD and SoAD in response to emotional face stimuli (see Barak & Feng, 2016 and Binelli et al., 2014 for reviews), as well as the differential amygdala activation observed in neurotypical individuals in response to faces paired with positive or negative behaviours (Baron et al., 2011; Charmet-Mougey et al., 2012), such research would further elucidate the neurological correlates of social behaviour across WS, ASD and SoAD. Likewise, future research would benefit from further considering how executive functioning difficulties may contribute to specific social behaviours known to be abnormal in WS, ASD and SoAD, such as visual attention and social approach judgments,

as well as more general aspects of social functioning that are affected in these conditions, such as social awareness and social communication.

Further research would also benefit from the development of experimental paradigms that more closely approximate everyday social interactions. Whilst we believe that the use of perceptually neutral face stimuli that are associated with salient biographical information is an important step in this direction, rather than solely relying on faces displaying emotional expressions, considerable adjustments can still be made. For instance, a similar biographical paradigm could be applied using virtual reality technology to explore social attention, in addition to approach and avoidance behaviours, in an environment that more closely resembles everyday social situations, whilst still retaining the experimental control of the laboratory environment. Such paradigms could also be utilised in social skills training programmes with the goal of improving and 'normalising' social interactions in individuals with WS, ASD or SoAD.

Conclusion

The current research provided a cross-disorder comparison of face scanpaths and initial attention patterns to faces in WS, ASD and SoAD individuals, utilising a novel biographical paradigm. Results suggested that group differences in face scanpaths and visual attention for biographical faces contribute to the divergent social profiles that characterise these disorders. Further, we found that executive functioning played a differential role in attention to the eyes in individuals with WS, ASD or SoAD. Our findings showed that visual attention for faces was abnormal across individuals with WS, ASD or SoAD and that specific executive functioning impairments within these disorders were associated with eye gaze abnormalities and, consequently, abnormal social behaviour in each of these conditions.

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Paper 4 – Appendix A

The BRIEF Rating Scale Structure

Indices and Composite Score	Clinical Scales	Behaviour Measured
Behavioural Regulation Index (BRI)	Inhibit	Ability to appropriately control behaviour; response inhibition
	Shift	Ability to move freely between situations or activities; cognitive flexibility
	Emotional Control	Ability to modulate emotional responses and reactions
Metacognitive Index (MI)	Initiate	Ability to generate ideas independently and begin a task
	Working Memory	Ability to hold information in mind with the goal of completing a task
	Plan/Organise	Ability to manage task demands, both current and future-oriented
	Organisation of Materials	Ability to order and organise one's everyday environment
	Monitor	Ability to consider and evaluate work and behaviour
Global Executive Composite (GEC)		Summary of clinical scales

Note. BRI = sum of Inhibit, Shift, and Emotional Control; MI = sum of Initiate, Working Memory, Plan/Organise, Organisation of Materials, and Monitor; GEC = sum of all clinical scales. Adapted from "Behavior Rating Inventory of Executive Function" by G. A. Gioia, P. K. Isquith, S. Guy, and L. Kenworthy, 2000a, p. 2.

Paper 4 – Appendix B

The BRIEF-A Rating Scale Structure

Indices and Composite Score	Clinical Scales	Behaviour Measured
Behavioural Regulation Index (BRI)	Inhibit	Ability to appropriately control behaviour; response inhibition
	Shift	Ability to move freely between situations or activities; cognitive flexibility
	Emotional Control	Ability to modulate emotional responses and reactions
	Self-Monitor	Ability to understand one's behaviour and the impact it may have on others
Metacognitive Index (MI)	Initiate	Ability to generate ideas independently and begin a task
	Working Memory	Ability to hold information in mind with the goal of completing a task
	Plan/Organise	Ability to manage task demands, both current and future-oriented
	Task Monitor	Ability to consider and evaluate one's own problem-solving ability
	Organisation of Materials	Ability to order and organise one's everyday environment
Global Executive Composite (GEC)		Summary of clinical scales

Note. BRI = sum of Inhibit, Shift, Emotional Control, and Self-Monitor; MI = sum of Initiate, Working Memory, Plan/Organise, Task Monitor, and Organisation of Materials; GEC = sum of all clinical scales. Adapted from "Behaviour Rating Inventory of Executive Function-Adult Version" by R. M. Roth, P. K. Isquith, and G. A. Gioia, G. A., 2005, p. 2. Copyright 2005 by the Psychological Assessment Resources, Inc.

Paper 5

Visual scanpaths and social approach judgements in Williams syndrome, Autism Spectrum Disorder and Social Anxiety Disorder: Use of Biographical rather than Affective stimuli

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Abstract

Williams syndrome (WS), Autism Spectrum Disorder (ASD) and Social Anxiety Disorder (SoAD) are conditions where atypical and divergent social approach and avoidance behaviours are observed. Despite these differences, poor social relations are observed across all conditions, which may stem from abnormalities in social processing. Using a cross-disorder comparison and a manipulation of biographical information, this study aimed to: (1) compare social approach judgments for biographical faces and (2) examine group differences in face scanpaths, specifically, time spent looking at the eye region of faces. Findings revealed that WS, ASD and SoAD individuals did not differ in their social approach judgements, however, face scanpaths revealed a dissociation between the groups. Whereas WS individuals spent more time looking at the eyes of faces paired with trustworthy biographical information, compared to those paired with untrustworthy biographical information, ASD and SoAD individuals displayed the opposite pattern. Findings suggest that the processes underlying social approach and avoidance behaviours are more complex than initially thought. Findings also highlight the benefits of cross-disorder comparisons in deepening our understanding of social behaviour.

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Introduction

Atypicalities in social behaviour, including social approach or avoidance, are common in individuals with neurodevelopmental or anxiety disorders (for example, see Plesa Skwerer (2017) and Wong and Rapee (2016)). Whereas heightened social approach is common in individuals with Williams syndrome (WS), increased social withdrawal and avoidance is typical of individuals with Autism Spectrum Disorder (ASD), as well as those with Social Anxiety Disorder (SoAD). These abnormalities in social approach and avoidance behaviours have been observed anecdotally and empirically (Asada & Itakura, 2012; Heeren & McNally, 2017), persist across the lifespan (Hofmann et al., 2015; Howlin & Udwin, 2006; Vivanti & Salomone, 2015), and contribute to poor social and mental health outcomes (Aderka et al., 2012; Jawaid et al., 2012) for affected individuals. In the case of WS, a rare neurodevelopmental condition with a microdeletion on chromosome 7 at 7q11.23 (Ewart, 1993), links to reduced stranger-danger awareness and an increased likelihood of exploitation are of major concern for parents and caregivers (Riby, Ridley, Lough, & Hanley, 2017).

The amygdala, a bilateral, almond-shaped structure located deep in the brain's medial temporal lobe and forming part of the limbic system, plays a major role in social approach and avoidance (Adolphs et al., 1998), as well as related functions including: processing and recognising facial emotion expressions (Adolphs et al., 1999; Palermo & Rhodes, 2007); threat detection (Ochsner & Gross, 2005); mediating autonomic arousal in response to faces (Davis & Whalen, 2001) and influencing eye gaze patterns (Adolphs et al., 2005). Structural and functional amygdala impairments are seen across WS, ASD and SoAD, suggesting a common neurological substrate despite disparate social behaviours

(Schumann et al., 2011).

Social approach behaviours in WS have been linked to increased right amygdala volumes (Martens et al., 2009) and, in WS individuals, happy faces elicit right amygdala hyperactivity, while threatening (angry and fearful) faces elicit hypoactivity in this region (Haas et al., 2009; Meyer-Lindenberg et al., 2005), consistent with the positive social bias seen in this disorder. In contrast, social avoidance behaviours have been linked to amygdala dysfunction in ASD and SoAD, by means of bilateral amygdala hyperactivity in response to direct eye gaze in ASD (regardless of the emotional expression) (Hadjikhani et al., 2017; Tottenham et al., 2014) and bilateral amygdala hyperactivity in response to angry faces in SoAD (Gentili et al., 2016). In addition to these established amygdala abnormalities, individuals with WS, ASD or SoAD each display anomalies in the way they recognise, process and respond to socially positive or socially threatening face stimuli during experimental tasks. There seem to be, at least at face value, parallels between general face processing findings and patterns of social approach/avoidance behaviours in people with these conditions.

Face Processing and Social Approach in WS, ASD and SoAD

In line with the role of the amygdala in social approach/avoidance and face processing, abnormal face scanning patterns and/or unusual attention biases towards or away from certain facial features or face types have been shown in all three aforementioned conditions. One skill that we use online to assist in deciding whether to approach or avoid a person is our rapid processing of facial features. Abnormal face scanning patterns and/or unusual attention biases towards or away from certain facial features or face types may disrupt this skill. In general, the face processing abnormalities seen in WS, ASD and SoAD tend to complement the social approach or avoidance behaviours typically observed in each specific condition.

For individuals with WS, who are drawn to social interaction, faces seem to be

particularly salient. Relative to neurotypical controls, WS individuals spend more time focused on faces generally (Riby & Hancock, 2009b), tend to spend more time looking at the eye region of both happy and angry faces during passive viewing paradigms (Porter et al., 2010), and spend more time looking at happy faces in particular (Kirk et al., 2013). This atypical face viewing is coupled with a strong positive social bias for happy or non-threatening faces (Bellugi et al., 1999). Happy faces in particular are judged as more approachable by WS individuals relative to neurotypical controls (Frigerio et al., 2006). Moreover, when compared to neurotypical controls, this positive social bias for happy faces is seen both neurologically and physiologically. WS individuals display amygdala hyperactivity (Haas et al., 2009), elevated heart rate and increased skin conductance responses (Jarvinen, Ng, Crivelli, Arnold, et al., 2015) when viewing happy faces. In contrast, individuals with WS display attenuated amygdala reactivity (Meyer-Lindenberg et al., 2005), heart rate deceleration and reduced skin conductance responses (Plesa Skwerer et al., 2009) when viewing angry and fearful faces. Similar findings are also demonstrated in WS at an attentional level, with heightened attentional biases towards happy expressions (Dodd & Porter, 2010; Goldman et al., 2016) and, at a cognitive level, with reduced attribution of negative intention (Godbee & Porter, 2013).

In stark contrast to WS, in ASD, where social avoidance is common, individuals generally spend less time looking at salient face features, such as the eyes (see Chita-Tegmark, 2016 for a recent meta-analysis). Moreover, ASD individuals spend less time focused on emotional faces overall, in comparison to neurotypical controls (see Black et al., 2017 for a review), as well as individuals with WS (Riby & Hancock, 2009, 2009a). These atypical scanpaths occur for both positive (e.g., happy) and threatening (e.g., angry) expressions (Black et al., 2017). In addition, findings seem consistent across static and dynamic stimuli (Riby & Hancock, 2009b). In contrast to the positive social bias seen in WS, there is evidence to suggest that ASD individuals display decreased approach

tendencies towards non-threatening (e.g., happy) faces (Kim et al., 2015) relative to neurotypical controls. This avoidance of faces is reflected neurologically in ASD, with evidence of amygdala hyperactivity for faces, regardless of their affective valence (Tottenham et al., 2014). Of note, recent findings suggest that experimentally manipulating gaze to the eye region potentiates this amygdala reactivity (Tottenham et al., 2014), highlighting the importance of the eyes for the development of social avoidance in ASD. Moreover, research considering physiological arousal to faces in ASD suggests that emotional faces (happy, fearful and neutral) elicit increased skin conductance responses when ASD individuals are compared to neurotypical controls, but surprisingly, not when they are compared to WS individuals (Jarvinen, Ng, Crivelli, Neumann, et al., 2015).

Somewhat similar to findings in ASD, in SoAD, where social difficulties are underpinned by a fear of negative evaluation, an avoidance of the eye region of faces – particularly those displaying threatening (e.g., angry) expressions – is often (Chen & Clarke, 2017), but not always (Boll et al., 2016), observed. Further, in line with the reported behavioural avoidance, happy and angry faces are judged as less approachable in comparison to neurotypical controls (see Kivity and Huppert (2016) for a recent meta-analysis). In a similar vein to ASD, this avoidance of threatening faces is observed neurologically, with functional neuroimaging research consistently reporting amygdala hyperactivity to angry and fearful faces (see Binelli et al., (2014) and Bruhl, Delsignore, Komossa and Weidt (2014) for meta-analyses). Additionally, recent findings suggest a physiological correlate for the social avoidance seen in SoAD, with increased skin conductance responses observed in response to direct, as opposed to averted, eye contact in affected individuals (Myllyneva, Ranta, & Hietanen, 2015).

Despite the documented differences in face processing and social approach, and links to amygdala anomalies, a consistent finding across prior studies has been the demonstration of ‘the expected rank order of approach’, with WS, ASD or SoAD

individuals typically judging non-threatening facial expressions as more approachable, relative to threatening expressions (Adolphs et al., 2001; Campbell et al., 2009; Porter et al., 2007). This expected rank order of approach is not observed in individuals with focal amygdala damage, such as stroke (Adolphs et al., 1998), suggesting other brain regions or networks are also be at play in the abnormal social approach behaviours of those with WS, ASD or SoAD. Moreover, as research in WS, ASD and SoAD has progressed, considerable individual heterogeneity in each of these disorders has been revealed, resulting in a lack of consensus across studies. For instance, in contrast to the findings outlined above, some WS individuals spend less time looking at the eye region of faces when identifying complex mental states (Hanley et al., 2013); some individuals with ASD judge negative faces as more approachable in comparison to neurotypical controls (Adolphs et al., 2001) and some SoAD individuals display increased attention to the eye region of both angry and happy faces (Boll et al., 2016). Such differences may represent clinical heterogeneity across and, indeed, within samples, or both, as well as differences in the stimuli used and the methodology adopted. To date, research has yet to directly compare social behaviour across WS, ASD and SoAD. Such a comparison would enhance our understanding of the face processing and social approach/avoidance behaviours that are either shared between disorders or specific to a single condition.

The Current Study

Although emotional expressions play a large role in helping us navigate the social world, they are not the only feature we use to guide social interactions and they are not the only possible manipulation of socially positive versus socially threatening stimuli. Biographical information learnt about a person, for example, can alert us to the potential threat they may pose in day to day social interactions, which may consequently inform our decisions of whether to engage in approach or avoidance behaviours. Indeed, research in neurotypical individuals suggests that faces associated with either positive or threatening

biographical knowledge elicit differential amygdala responses, similar to the differential responses observed for socially positive versus socially threatening emotional expressions. Charmet-Mougey, Rich, and Williams (2012) found that faces associated with negative biographical information elicited increased amygdala reactivity in comparison to faces associated with positive biographical information. In line with these neurological findings, recent behavioural findings in neurotypical adults suggest that associating neutral faces with positive or negative behaviours influences subsequent evaluation and likeability ratings of the same faces (Abdel Rahman, 2011; Verosky et al., 2018).

No study to date has investigated approach judgments and face scanpaths in WS, ASD or SoAD using faces that are perceptually neutral, but biographically salient. Such an investigation would serve to further our understanding of how abnormalities in face processing contribute to social approach and avoidance behaviours, particularly given the underlying amygdala anomalies across these three conditions. We explored group differences in approach judgements and face scanpaths for trustworthy characters – perceptually neutral face stimuli paired with trustworthy biographical information and untrustworthy characters – perceptually neutral face stimuli paired with untrustworthy biographical information. There was also a neutral condition comprised of perceptually neutral face stimuli paired with neutral biographical information to control for biographical memory. Further, given that this experimental task required individuals to make approach judgments whilst eye movements were recorded, we included an approach scale (utilised without measuring scanpaths in previous studies looking at approach judgments in WS), beneath each face and investigated group differences in the amount of time spent looking at the options on this scale in each group, across character types (e.g., see Bellugi et al., 1999).

The primary aims of the current study were: (1) to examine the influence of biographical information on approach judgments in WS, ASD and SoAD groups, as well

as neurotypical controls; (2) to examine group differences in the proportion of time spent viewing the eye region of faces when biographical stimuli, as opposed to emotional expressions, are manipulated and (3) to examine the proportion of time spent looking at the positive (approach) versus negative (do not approach) ends of the approach scale and whether this differed by character type.

For all aims we were interested in between- and within-group differences for trustworthy, neutral and untrustworthy characters. Between-group differences were examined by looking at differences in approach judgements and face scanpaths for trustworthy, neutral and untrustworthy characters between the clinical and neurotypical groups. Within-group differences were examined by comparing approach judgments and face scanpaths for trustworthy, neutral and untrustworthy characters within each group. Given the research suggesting that approach judgements and face scanpaths are influenced, to varying degrees, by emotional expression in WS (Frigerio et al., 2006; Kirk et al., 2013), ASD (Chita-Tegmark, 2016; Kim et al., 2015), and SoAD (Chen & Clarke, 2017; Kivity & Huppert, 2016), we explored how approach judgements and face scanpaths change depending on the type of biographical information (trustworthy, neutral or untrustworthy) paired with the face.

Following from Frigerio et al. (2006), albeit where happy faces were used as the socially positive stimulus, we hypothesised that the WS group would judge trustworthy characters as significantly *more* approachable than the ASD, SoAD and neurotypical control groups and, in line with Kim et al. (2015) and Kivity and Huppert (2016) where happy faces were similarly used as the socially positive stimulus, we predicted that the ASD and SoAD groups would judge trustworthy characters as significantly *less* approachable than the WS and neurotypical control groups. In line with previous research, albeit utilising different stimuli (biographical here as opposed to emotional facial expression in previous research), we hypothesised that all groups would demonstrate the

expected rank order of approach, judging trustworthy characters to be more approachable than neutral characters and judging untrustworthy characters as least approachable (Campbell et al., 2009; Porter et al., 2007).

With respect to face scanpaths, we hypothesised that WS individuals would spend more time looking at the eye region of faces relative to ASD individuals, irrespective of the biographical information the faces had been associated with, in line with Riby and Hancock (2009b) . Although this is the first study to directly compare face scanpaths in WS and SoAD, based on the findings of increased time spent looking at the eyes of both happy and angry faces in WS (Porter et al., 2010) and decreased time spent looking at the eyes, particularly of angry faces, in SoAD (Chen & Clarke, 2017), we predicted that WS individuals would spend more time looking at the eye region of faces compared to SoAD individuals. Specifically, we predicted that this effect would occur for trustworthy, neutral and untrustworthy characters, however, that the largest effect would be observed for untrustworthy characters. Given the divergent prior findings (Hanley et al., 2013; Porter et al., 2010), we made no specific predictions as to whether WS individuals would spend more time looking at the eye region of faces relative to neurotypical controls, or whether this would vary as a function of character type. Moreover, in line with Black et al. (2017), albeit where studies using various emotional expressions were reviewed, we predicted that ASD individuals would spend less time looking at the eye region of all faces, irrespective of character type, compared to neurotypical controls. Additionally, in line with the findings of Chen and Clarke (2017), where studies using angry faces as the socially threatening stimulus were reviewed, we hypothesised that the time spent looking at the eye region of faces would be modulated by biographical information in SoAD individuals, such that the SoAD group would spend less time looking at the eye regions of untrustworthy characters compared to neurotypical controls.

Considering within-group differences for face scanpaths, following from

suggestions that avoidance of the eyes is modulated by emotional expression in SoAD and is most prominent for angry faces (Chen & Clarke, 2017), we anticipated that SoAD individuals would spend less time looking at the eye regions of untrustworthy characters, relative to trustworthy characters. In line with prior literature that has found no evidence of within-group differences for time spent looking at the eye region across emotional expressions in WS or ASD (Black et al., 2017; Porter et al., 2010), we did not predict that the time spent looking at the eye region of faces would vary as a function of character type in these groups.

In relation to our third aim, while including the approach scale was exploratory, we predicted that the amount of time spent looking at the various approach scale options would differ as a function of character types, and possibly differ across groups given the abnormalities in social approach/avoidance reported across these populations. More specifically, we predicted that participants would spend more time looking at the positive (approach) end of the approach scale for trustworthy characters and the negative (do not approach) end of the approach scale for untrustworthy characters.

Method

Participants

The study involved 75 participants, including 15 participants each with WS, ASD or SoAD, and 30 neurotypical participants (15 matched to all clinical groups on chronological age and 15 matched to WS participants on mental age). These participants were recruited for a series of studies, as reported in Boulton and Porter (2017); Boulton et al. (2018a, 2018b, 2018c). A mental age comparison group was included to accommodate the intellectual disability in the WS group. WS, ASD, SoAD and chronological-age matched neurotypical participants were matched at a group level on chronological age (CA) and WS and mental-age matched neurotypical participants were matched at a group level on mental age (MA). No evidence of intellectual disability was observed in either the

ASD or the SoAD group. The Woodcock-Johnson Tests of Cognitive Ability – 3rd Edition (WJ-III COG; Woodcock, McGrew, & Mather, 2001) was used to obtain a measure of verbal and spatial abilities (see below for details). The study was approved by the Macquarie University Human Research Ethics Committee. Informed consent was obtained from the participants or their parents/caregivers, as appropriate.

Williams syndrome group. WS participants (7 male, 8 female) aged between 11.33 and 43.75 years (*M*=19.96*; SD*=8.06), were recruited through Williams Syndrome Australia Limited and had a positive fluorescent in situ hybridisation (FISH) test with deletion of the elastin gene at 7q11.23 (Fryssira et al., 1997). For the WS group, exclusionary criteria included: a co-morbid neurological condition/insult or a clinical diagnosis that was not related to the primary diagnosis of WS. No participants met exclusionary criteria. Verbal ability standard scores using the Verbal Comprehension subtest from the WJ-III COG ranged from 56 to 91 (*M*=69.07; *SD*=10.25) and spatial-perceptual ability standard scores using the Spatial Relations subtest from the WJ-III COG ranged from 55 to 90 (*M*=76.71; *SD*=9.14)[10].

Autism spectrum disorder group. ASD participants (9 male, 6 female) aged between 11.00 and 42.50 years (*M*=25.98*; SD*=9.17), were recruited through Autism Spectrum Australia. Participants met criteria for ASD according to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5; American Psychiatric Association, 2013), confirmed by study authors MP or QW, qualified and registered psychologists and had also previously received a formal diagnosis of Autism or Asperger syndrome from a clinical psychologist. ASD participants also met clinical cut-offs for

[10] Although scores on the Spatial Relations subtest of the WJ-III COG may seem higher than one would expect given the general cognitive profile for WS, this is likely due to the absence of a construction component in this subtest, an area of functioning that is more commonly impaired in WS individuals (Porter & Coltheart, 2008). Further, performance on the equivalent version of this subtest in the Woodcock-Johnson Tests of Cognitive Ability-Revised has been found to be a cognitive strength in some subgroups of WS individuals (Porter & Coltheart, 2005), which may help to explain scores in the present study.

deficiencies in reciprocal social behaviour on the Social Responsiveness Scale-2nd Edition (SRS-2; Constantino & Gruber, 2012). In the case of child ASD participants, the School-Age Form was completed by parents, while adult ASD participants completed the Adult Self-Report Form. Additionally, the Ritvo Asperger and Autism Diagnostic Scale-Revised (RAADS-R; Ritvo et al., 2011) was completed by adult ASD participants. The RAADS-R is a self-report diagnostic measure, designed for assisting in the diagnosis of ASD in adults with average intelligence. Scores for all participants were above the diagnostic threshold of 65 on this measure, consistent with a diagnosis of ASD (Ritvo et al., 2011). For the ASD group, exclusionary criteria included a co-morbid neurological condition/insult, intellectual disability or a clinical diagnosis unrelated to the primary diagnosis of ASD. No participants met exclusionary criteria. Verbal ability standard scores using the Verbal Comprehension subtest from the WJ-III COG ranged from 84 to 125 (*M*=107.00; *SD*=11.95) and spatial ability standard scores using the Spatial Relations subtest from the WJ-III COG ranged from 94 to 133 (*M*=110.27; *SD*=9.07).

Social anxiety disorder group. SoAD participants (1 male, 14 female) aged between 14.50 and 43.33 years (*M*=21.81*; SD*=6.91), were recruited through the Centre for Emotional Health, a research and treatment clinic focused on the treatment and prevention of mental health problems including anxiety, located at Macquarie University (*N*=7) or through Macquarie University via advertisements placed around campus (*N*=8). A diagnosis of SoAD was made using the Anxiety and Related Disorders Interview Schedule for DSM-5 (ADIS-5; Brown & Barlow, 2014) for adult participants or the parent and child versions of the Anxiety Disorders Interview Schedule for Children for DSM-IV (ADIS-C/P; Silverman & Albano, 1996) for child participants. Trained clinicians conducted all interviews, including co-author QW. Diagnoses were rated on a severity scale from 0 to 8, with a rating of 4 or higher indicating that symptoms are causing significant life interference. All participants received a principal diagnosis of SoAD, and

the presence of other anxiety and mood disorders was allowed (13% of the SoAD group met criteria for an additional anxiety disorder and 53% met criteria for a mood disorder). For the SoAD group, exclusionary criteria included a neurodevelopmental disorder, such as ASD, a co-morbid neurological condition/insult or intellectual disability. No participants met exclusionary criteria. Verbal ability standard scores using the Verbal Comprehension subtest from the WJ-III COG ranged from 93 to 120, (*M*=102.93; *SD*=8.05) and spatial ability standard scores using the Spatial Relations subtest from the WJ-III COG ranged from 88 to 116 (*M*=100.40; *SD*=8.14).

Chronological age control group. CA-matched neurotypical participants (6 male, 9 female) aged between 11.42 and 42.83 years (*M*=21.97*; SD*=7.98), were recruited through the Macquarie University Neuronauts Kids Science Club, a register of children and adolescents who elect to take part in research projects at Macquarie University or through the Macquarie University psychology participation pool, a register of undergraduate University students who participate in research in return for course credit. For the CA-matched control group, exclusionary criteria included a prior neurological condition or insult, a history of developmental delay,) intellectual disability (indexed by verbal or spatial ability scores ≤ 70), or a clinical diagnosis (such as a psychological condition or sensory impairment). No participants met exclusionary criteria. Verbal ability standard scores using the Verbal Comprehension subtest from the WJ-III COG ranged from 83 to 114, (*M*=96.57; *SD*=10.20) and spatial ability standard scores using the Spatial Relations subtest from the WJ-III COG ranged from 89 to 109 (*M*=99.57; *SD*=7.57).

Mental age control group. MA-matched neurotypical participants (8 male, 7 female) aged between 6.33 and 11.08 years (*M*=8.43; *SD*=1.43), were recruited though the Macquarie University Neuronauts Kids Science Club. The same exclusionary criteria were used as for the CA-matched control group. No participants met exclusionary criteria. An average of mental age equivalency on the verbal and spatial tasks (see below for task

descriptions) was used to match neurotypical children to WS participants. Verbal ability standard scores using the Verbal Comprehension subtest from the WJ-III COG ranged from 94 to 127, (*M*=105.77; *SD*=9.78) and spatial ability standard scores using the Spatial Relations subtest from the WJ-III COG ranged from 89 to 114 (*M*=99.15; *SD*=8.49).

Measures and Procedure

Woodcock-Johnson Tests of Cognitive Ability – 3rd Edition (WJ-III COG; Woodcock et al., 2001). The subtests Verbal Comprehension and Spatial Relations from the WJ-III COG (Woodcock et al., 2001) were used to obtain estimates of verbal and non-verbal (spatial-perceptual) ability. Verbal Comprehension requires participants to name objects, provide synonyms and antonyms for a range of words, and complete verbal analogies. Spatial Relations involves looking at shapes and determining which pieces (from a selection of five options) would, when oriented correctly, join together to create the completed shape. These subtests reliably measure comprehension-knowledge (*Gc*) and visual-spatial thinking (*Gv*), with median reliabilities of 0.97 and 0.86, respectively (Woodcock et al., 2001).

Biographical learning task. The current study employed a biographical face learning paradigm, originally developed by Charmet-Mougey et al. (2012) for use in neurotypical adults. This paradigm has since been modified for use with neurotypical children and individuals with WS (Boulton & Porter, 2017) and has also been used successfully with ASD and SoAD populations (Boulton et al., 2018a, 2018b, 2018c). Images from 24 different actors (12 male, 12 female), displaying neutral expressions were displayed to participants. Images were selected from the NimStim standardised face set and all identities selected were reliably identified as expressing neutral expressions by independent raters (Tottenham et al., 2009). The 24 faces were divided into three blocks. A fictional biographical vignette was presented with each block of faces, describing the individuals as: (1) *trustworthy characters*, where the faces were described as belonging to

individuals who were trustworthy or 'good'; (2) *neutral characters,* where the faces were described as belonging to individuals who were neutral or 'neither good nor bad' and (3) *untrustworthy characters*, where the faces were described as belonging to individuals who were untrustworthy or 'bad'. Each block comprised four male and four female faces. The character types corresponding to each block were counterbalanced across participants to control for biases in responding. Counterbalancing was also employed to control for differences in perceived trustworthiness between faces.

To facilitate learning, separate training and testing phases were conducted. During the training phase, each block of faces was presented with a colour tint. LunaPic online picture editing software (www.lunapic.com) was used to tint each block blue, purple or orange. These colours were selected as they were considered to be relatively neutral and unlikely to be implicitly associated with emotionally salient information (Sutton & Altarriba, 2016; Takahashi & Kawabata, 2018). Colour tints were counterbalanced across conditions (blocks) and participants. Before each block of faces was presented, the corresponding biographical vignette (trustworthy characters, neutral characters, untrustworthy characters) was read aloud to the participant by the experimenter. Participants were instructed to look at each face until they believed they had memorised which character type it belonged to. Participants were able to look at the faces as many times as they liked and for as long as they liked. Once participants felt confident that they had memorised each face, the testing phase commenced. Each face was presented in greyscale and participants were asked to identify the character type of each face. Participants were provided with instant feedback after responding, and the eye-tracking experiment was not completed until participants were able to correctly label the character type of each face (when presented in greyscale) at an accuracy level of at least 80 percent. Participants were able to go back and look at the training stimuli (faces grouped by vignette type with colour tints) as often as they liked in order to help them remember the character type for each face. Once an accuracy level of at

least 80% had been established for all participants, social approach judgments and eye movements were recorded using the faces in greyscale.

Social approach judgments. To assess approach-avoidance tendencies, we used a social approach task similar to that administered by Bellugi et al. (1999). Participants were shown each biographical face and were asked to indicate how much they would like to go up and talk to the person. To assist with participant ratings, the approach scale from Bellugi et al. (1999) was used. This scale has been successfully used with WS individuals in numerous prior studies (Jones et al., 2000; Porter et al., 2007) and includes five response options: "yes", "maybe", "don't know", "probably not", and "no". In line with Bellugi et al. (1999) and Porter et al. (2007), ratings were numerically coded: "yes" = 2; "maybe" = 1; "don't know" = 0; "probably not" = -1; "no" = -2. Scores were then averaged for each character type, with positive values indicating a high likelihood of approach, and negative values indicating a low likelihood of approach.

Participants viewed the images on a Samsung 27-inch LED monitor from a distance of 60cm (viewing distance was controlled by seat position). The face images were 13.44cm (506 pixels) wide by 16.35cm (618 pixels) high and presented in greyscale, with the hair showing. The approach scale was inserted below each face, giving the entire image a size of 17.15cm (648 pixels) wide by 22.60cm (854 pixels) high, creating a horizontal visual angle of 16.27° and a vertical visual angle of 21.33°. Images were displayed in a pseudorandom order for each participant and were presented for 10 seconds. All images appeared in the centre of the computer screen. Eye movements were recorded while participants made approach judgements. On observation, participants generally made a judgement within a few seconds, with the researcher directing their attention to the task when necessary.

Face scanpaths. Eye movements were recorded with an Eyelink-II gaze monitoring system (SR Research Ltd), sampling at a temporal resolution of 500 Hz and a

spatial resolution of 0.2°. An eye movement was classified as a saccade when its distance exceeded 0.2° and velocity reached 30°/s, or when its length exceeded 0.2° and its acceleration had reached 8,000°/s^2. The head-mounted apparatus used to record eye movements was adjusted to obtain binocular eye movements. Before the experiment began a nine-point calibration of eye-fixation relative to the screen was conducted. Participants viewed a centrally placed black dot (10mm in diameter) with a white centre (2mm in diameter) that moved to eight locations around the centre and periphery of the screen. Each participant was asked to fixate on the dot and track its movements around their screen with their eyes. The dot moved to a new location once the computer had recorded an adequate corneal 'lock' from the participant, which required at least 1,000ms viewing in each location of the dot. A successful calibration indicated that a robust fixation recording could be obtained across the width and breadth of the computer monitor. A successful calibration was achieved for all participants. The initial point of retinal attention during social approach task was controlled by a black cross presented on either the left or right of the screen for 2,000ms immediately prior to each face stimulus.

Before each image appeared on the screen participants were instructed to stare at a fixation cross, which was programmed to appear either on the left or right side of the screen. This procedure ensured that all participants were attending to the same part of the screen when the stimulus appeared. Importantly, this fixation cross was not positioned on any region of the face. The fixation cross appeared equally on the left and right sides of the screen, in a random order. Manual experimenter control initiated each trial, and each face was presented for 10,000 ms. While previous studies have used shorter display times, 10,000 ms was selected to allow sufficient time to assess gaze patterns across the eye region and approach scale, and to determine if there were differential eye movement patterns across participant groups and between faces paired with trustworthy, neutral or untrustworthy biographical information.

Defining areas of interest (AOIs): Regions of interest were drawn on each facial image using the manual drawing functions provided in the EyeLink Data Viewer software. Three facial AOIs were defined including left eye, right eye and brow. As the present study was primarily interested in the eye region as a whole, data was averaged over the eye and brow regions ("eye region") rather than conducting individual analyses for each eye and brow. However, to ensure no lateralisation effects were present, the percentage of fixations and mean dwell time percentage to the left eye and right eye were compared using independent-group ANOVAs; no significant differences were observed. A further five AOIs were added, outlining each response box on the approach scale. These AOIs included 'yes' 'maybe' 'don't know' 'probably not' and 'no'. As we were primarily interested in whether participants looked more at the positive ('yes' and 'maybe') or negative ('probably not' and 'no') options on the scale for faces paired with trustworthy, neutral or untrustworthy biographical information, data was averaged over the 'yes' and 'maybe' options, and over the 'probably not' and 'no' options rather than conducting individual analyses for each approach option. Therefore, all analyses described used AOIs defined as (1) eye region; (2) positive (approach) scale options; and (3) negative (do not approach) scale options. Example AOIs are shown in Figure 1.

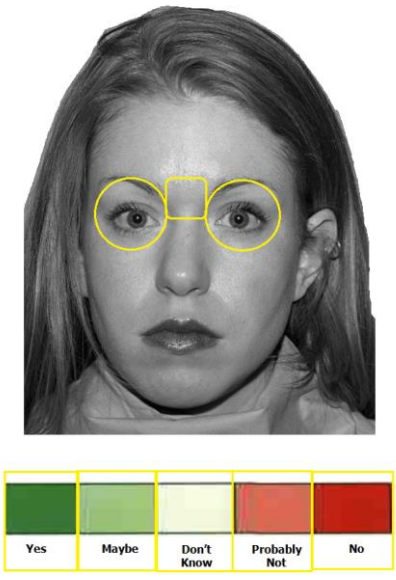

Figure 1. An example of the defined areas of interest.

Visual scanpath parameters: Visual scanpath (VSP) parameters included: Mean Fixation percentage (the mean percentage of fixations made in each AOI) and Mean Dwell Time Percent (the mean percentage of time spent fixating in each AOI). As in previous studies (Lewis et al., 2017; Porter et al., 2010), there were no differences in the results between Mean Fixation percentage and Mean Dwell Time percent, so only the latter is reported here.

In order to account for inter-individual variability in the time spent fixating on the face, and to focus our analysis on when participants were 'on task' and looking at either the face or approach scale, we generated a Proportional Mean Dwell Time Percent to Eye Region. This was defined as Mean Dwell Time Percent to Eye Region divided by Mean Dwell Time Percent to whole face (including approach scale). This variable was used for analyses investigating the differences in proportion of time spent looking at eye regions across the whole viewing period. With respect to time spent looking at the approach scale, in order to focus our analysis on when participants were looking only at the approach scale, we generated a Proportional Mean Dwell Time Percent to Positive Scale Options. This was defined as Mean Dwell Time Percent to Positive Scale Options divided by Mean Dwell Time Percent to Whole Approach Scale. The same calculation was employed to generate a Proportional Mean Dwell Time Percent to Negative Scale Options. These variables were used for analyses investigating the differences in proportion of time spent looking at positive and negative approach scale options for faces paired with differing biographical information.

Statistical Analysis

All statistical analyses were conducted using SPSS version 24 (IBM). Fisher's exact test was used to explore group differences on categorical variables (i.e., sex). One-way analyses of variance (ANOVAs) were used to explore group differences on continuous variables, such as CA and MA.

For the approach ratings and eye-tracking data, Shapiro-Wilk tests were used to check assumptions of normality. Normality assumptions were met, therefore repeated measures ANOVAs were used to address our aims. With regards to follow-up analyses, we made an a priori decision to only compare the MA-matched control group to the WS group, given that the rationale for including the former group was to compare WS participants to MA-matched peers. Greenhouse-Geisser corrections are reported whenever the assumption of sphericity was violated. As a result of the small sample size, and in an effort to minimise the likelihood of a Type-II error, corrections for multiple comparisons were not applied and alpha was set to 0.05 for all following analyses (see Rothman, 1990). Cohen's *d* effect sizes are reported for all pairwise comparisons, with 0.2 indicating a small effect, 0.5 a medium effect, and 0.8 a large effect (Cohen, 1988).

Results

Demographic information for each group is displayed in Table 1. There was no significant difference in chronological age between the WS, ASD, SoAD and CA control groups (p=.229), nor was there a significant difference in mental age between the WS and MA control groups (p=.897). The groups were found to differ in sex due to the SoAD group being predominantly composed of females (p=.020). A recent review has reported higher prevalence rates of SoAD, as well as elevated clinical severity of the disorder in women (Asher et al., 2017), which may explain the increased proportion of females in this sample. Excluding the SoAD participants, there were no significant group differences in sex (p=.823).

Group differences in verbal ability were observed; standard scores in the ASD, SoAD, CA- and MA-matched comparison groups were significantly higher than those in the WS group (all p-values <.001). Similarly, group differences in spatial ability were observed; standard scores in the ASD group were significantly higher than those in the SoAD and CA-matched control groups (all p-values <.004) while standard scores in the

ASD, SoAD, CA-matched and MA-matched comparison groups were significantly higher than those in the WS group (all *p*-values <.001). Given the group differences in verbal and spatial ability, we assessed whether these variables were related to our dependent variables of interest, namely, social approach judgments, mean proportional dwell time to the eye region or mean proportional dwell time to positive and negative options on the approach scale. Neither verbal nor spatial ability were related to our dependent variables of interest within any group (all *p*-values >.074). Whilst a standard approach in instances of between-group differences in cognitive ability is to control for cognitive ability statistically, this can increase the likelihood of Type-II error. Additionally, the suitability of including cognitive ability as a covariate when the relationship between cognitive ability and the dependent variable(s) of interest differs across groups has been brought into question (for a broader discussion see Dennis et al., 2009 and Miller & Chapman, 2001). Given that much of the literature covaries for cognitive ability in instances such as ours (although, see Jarivinen, Ng & Bellugi, 2015 and Jarvinen et al., 2015 for recent exceptions), we conducted all analyses with and without verbal and spatial ability included as covariates and found that the pattern of results did not differ. Thus, we report the results of the simple models without covariates. This methodology also aligns with that recently employed by Chevallier et al. (2015) in ASD individuals.

Table 1

Demographic characteristics for each group.

	CA	ASD	SoAD	WS	MA	$p^{a,}$
	n=15	*n*=15	*n*=15	*n*=15	*n*=15	
Chronological Age (years)	21.97 (7.98)	25.98 (9.17)	21.81 (6.91)	19.96 (8.06)	8.43 (1.43)	0.23
Mental Age (years)	–	–	–	7.72 (2.05)	7.81 (1.74)	0.90
Sex (n, % Female)	9 (60%)	6 (40%)	14 (93%)	8 (53%)	7 (47%)	0.02

Note: [a]*p*-value for ANOVA (chronological age) independent samples *t*-test (mental age) and Fisher's exact test (sex) for any group differences. CA = Chronological age-matched controls; ASD = Autism Spectrum Disorder; SoAD = Social Anxiety Disorder; WS = Williams syndrome; MA = mental age-matched controls. Data expressed as mean (SD).

Social Approach Judgments

Average social approach judgments for the clinical and control groups are presented in Table 2. An ANOVA with Group as the between-subjects factor and Biogrpahical Information as the within-subjects factor (trustworthy, neutral, untrustworthy) was conducted to examine group differences on approach judgments. Results revealed that neither the main effect of Group, $F(1,70)=.253$, $p=.907$, partial $\eta^2=.014$, nor the interaction of Group by Biogrpahical Information, $F(7.08,123.97)=1.64$, $p=.13$, partial $\eta^2=.086$, were statistically significant. The only significant result was a main effect of Biogrpahical Information, $F(1.77,123.97)=172.69$, $p<.001$, partial $\eta^2=.712$. Follow-up comparisons revealed that approach judgments for faces that had been associated with trustworthy biographical information ($M=0.94$; $SD=0.67$) were significantly higher than those for faces that had been associated with neutral biographical information ($M=0.21$; $SD=0.85$) and untrustworthy biographical information ($M=–1.12$; $SD=0.74$) across all participants (all p-values <.001). Similarly, approach judgments for faces that had been associated with neutral biographical information were significantly higher than those for faces that had been associated with untrustworthy biographical information (p <.001). In sum, all participants, irrespective of group, demonstrated the expected rank order of approach, as seen in Figure 2.

Table 2

Approach judgments for each group and condition on the social approach task.

	ASD	SoAD	WS	CA	MA
Trustworthy	0.88 (0.74)	0.85 (0.59)	1.08 (0.60)	1.17 (0.76)	0.71 (0.66)
Neutral	0.19 (0.96)	0.17 (0.80)	0.38 (1.02)	0.20 (0.67)	0.12 (0.83)
Untrustworthy	-1.24 (0.62)	-0.78 (0.97)	-1.21 (0.66)	-1.44 (0.56)	-0.90 (0.71)
Overall	-0.06 (0.46)	0.08 (0.52)	0.08 (0.54)	-0.02 (0.43)	-0.03 (0.59)

Note: ASD = Autism Spectrum Disorder; SoAD = Social Anxiety Disorder; WS = Williams syndrome; CA = Chronological age-matched controls; MA = mental age-matched controls. Data expressed as mean (SD).

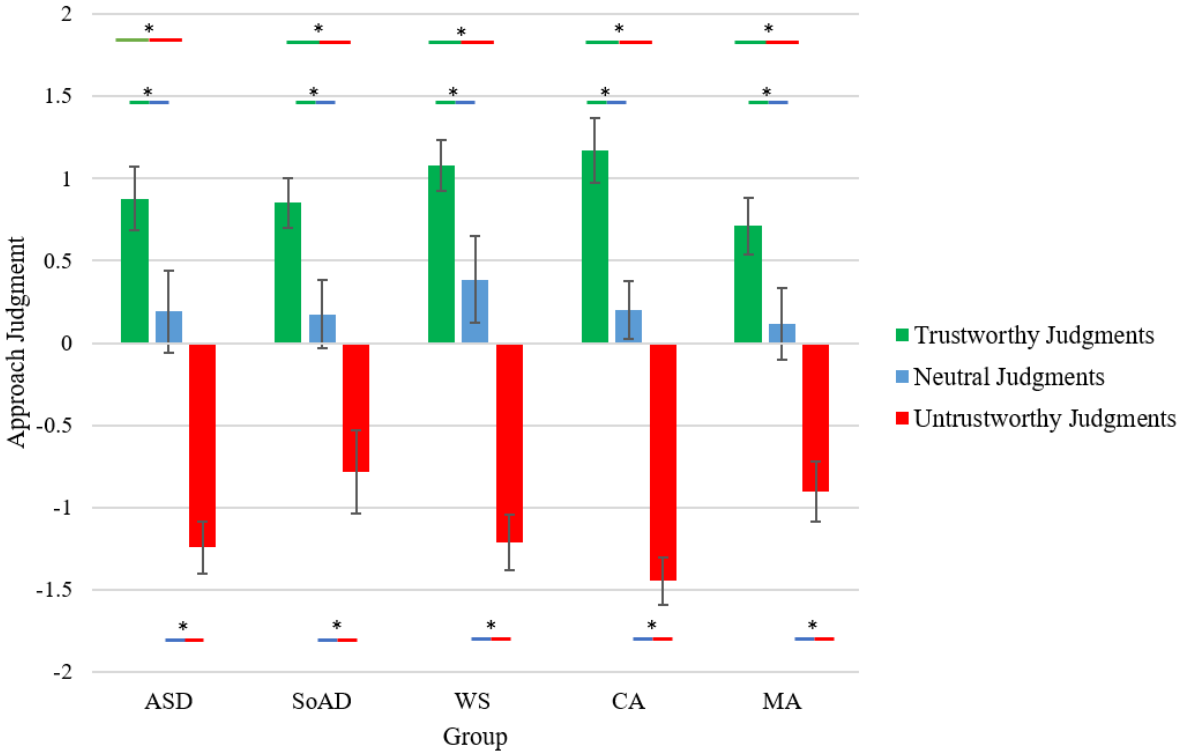

Figure 2. Average approach judgments for biographical faces by group. Error bars represent standard error. * indicates $p<.05$.

Face Scanpaths

A repeated measures ANOVA with Group as the between-subjects factor and Biographical Information (trustworthy, neutral, untrustworthy) as the within-subjects factor was conducted to examine group differences in the proportion of time spent looking at the eye region across the whole trial period. While the main effect of Biographical Information was not statistically significant, $F(1.79,125.09)=.62$, $p=.540$, partial $\eta^2=.009$, there was a significant main effect of Group, $F(4,70)=6.49$, $p<.001$, partial $\eta^2=.27$, and a significant Group by Biographical Information interaction, $F(7.15,125.09)=2.24$, $p=.034$, partial $\eta^2=.11$. To decompose this interaction, we looked separately at between- and within-group differences in the proportion of time spent looking at the eye region for faces associated with differing biographical information.

Considering between-group differences in the proportion of time spent looking at

the eye region, follow-up comparisons revealed that, compared to WS participants, SoAD participants spent a significantly larger proportion of time looking at the eye region of faces that had been associated with untrustworthy biographical information, $t(70)=2.94$, $p=.004$, $d=0.88$. A similar result was observed when comparing the SoAD and CA-matched control groups, with participants in the SoAD group spending a significantly larger proportion of time looking at the eye region of faces that had been associated with untrustworthy biographical information, compared to neurotypical controls, $t(70)=2.15$, $p=.034$ $d=0.69$. Further, when compared to MA-matched control participants, WS participants spent a significantly larger proportion of time looking at the eye region of faces irrespective of the type of biographical information the face had previously been paired with, p-values <.020. No other follow-up comparisons reached statistical significance. The between-group results for mean proportion of time spent looking at the eye region of faces are depicted in Figure 3.

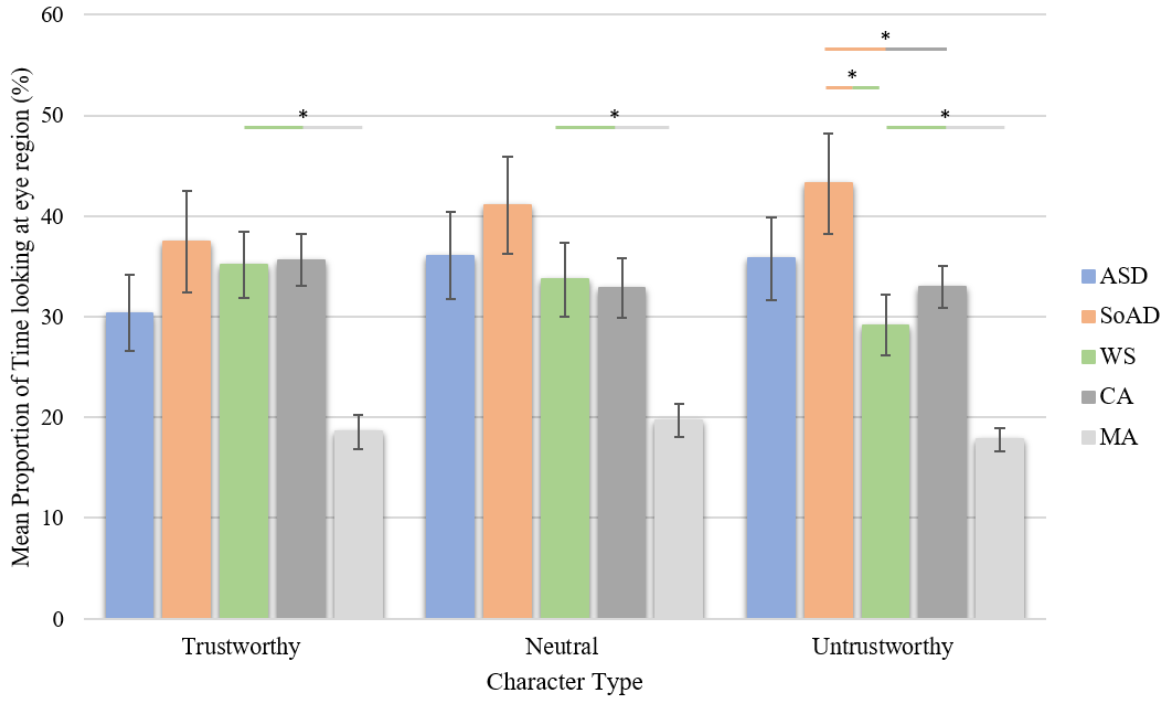

Figure 3. Between-group differences in mean proportion of time spent looking at eye region. Error bars represent standard error. * indicates p <.05.

When considering within-group differences in the proportion of time spent looking

at the eye region across the whole trial period, follow-up comparisons revealed that WS individuals spent a significantly larger proportion of time looking at the eye region of faces that had been associated with trustworthy biographical information, relative to those that had been associated with untrustworthy biographical information, $t(70)=2.73$, $p=.009$, $d=0.68$. Within the ASD group, we observed the opposite pattern, with ASD individuals spending a significantly larger proportion of time looking at the eye region of faces that had been associated with untrustworthy biographical information, relative to those that had been associated with trustworthy biographical information, $t(70)=2.45$, $p=.018$, $d=0.69$. A similar scanpath pattern to that seen in ASD was observed in the SoAD group, $t(70)=2.64$, $p=.011$, $d=0.56$. Of note, ASD participants also spent a larger proportion of time looking at the eye region of faces that had been associated with neutral biographical information, relative to faces that had been associated with trustworthy biographical information, however this effect failed to reach statistical significance, $t(140)=1.91$, $p=.060$, $d=0.42$, likely due to the increased variability in the proportion of time spent looking at faces paired with neutral biographical information ($M=36.08$; $SD=16.85$), relative to that seen when looking at faces paired with untrustworthy biographical information, ($M=35.76$; $SD=15.73$). These results are illustrated in Figure 4. No within-group differences were observed in CA- nor MA-matched neurotypical controls when considering the proportion of time spent looking at the eye region (all p-values>.23).

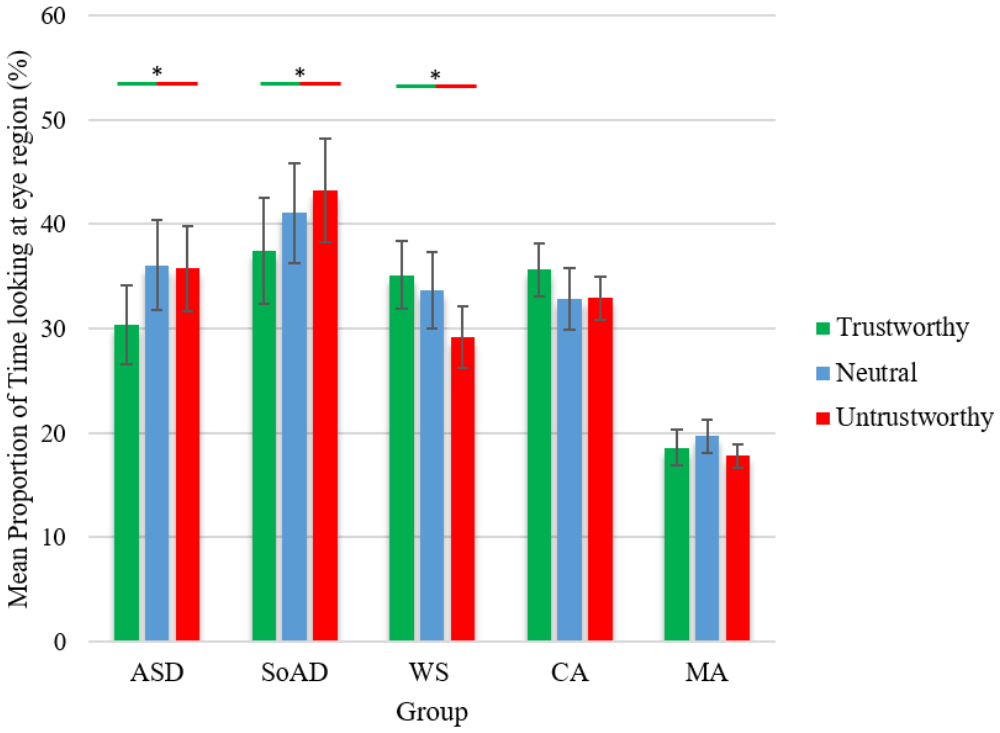

Figure 4. Within-group differences in proportion of time spent looking at eye region. Error bars represent standard error. * indicates $p<.05$.

Approach Scale Scanpaths

To explore group differences in the proportion of time spent looking at the positive and negative options on the approach scale for faces associated with differing biographical information, we conducted a repeated measures ANOVA with Group as the between-subjects factor and Biographical Information (trustworthy, neutral, untrustworthy) and Scale Option (positive, negative) as within-subjects factors. There was no significant main effect of Scale Option, nor of Group (p-values > .49), however the main effect of Biographical Information was statistically significant, $F(1,38)=36.17$, $p<.01$, partial $\eta^2=.34$. Further, there was a statistically significant Biographical Information by Scale Option interaction, $F(1.38,95.04)=7.66$, $p=.003$, partial $\eta^2=.10$. Neither the Group by Biographical Information interaction, nor the Group by Biographical Information by Scale Option interaction reached statistical significance; $p=.43$ and $p=.71$, respectively.

To explore the significant Biographical Information by Scale Option interaction, follow-up analyses were conducted on the sample as a whole. These analyses revealed that the proportion of time spent looking at the approach scale options differed as a function of biographical information. As illustrated in Figure 5, on average, participants spent a significantly larger proportion of time looking at the positive (approach) options on the approach scale (relative to the negative options) for faces that had been associated with trustworthy biographical information, $t(74)=3.37$, $p=.001$, $d=0.41$, and a significantly larger proportion of time looking at the negative (do not approach) options on the approach scale (relative to the positive options) for faces that had been associated with untrustworthy biographical information, $t(74)=–6.23$, $p<.001$, $d=0.77$. No such differences were observed for faces that had been associated with neutral biographical information, $p=.36$.

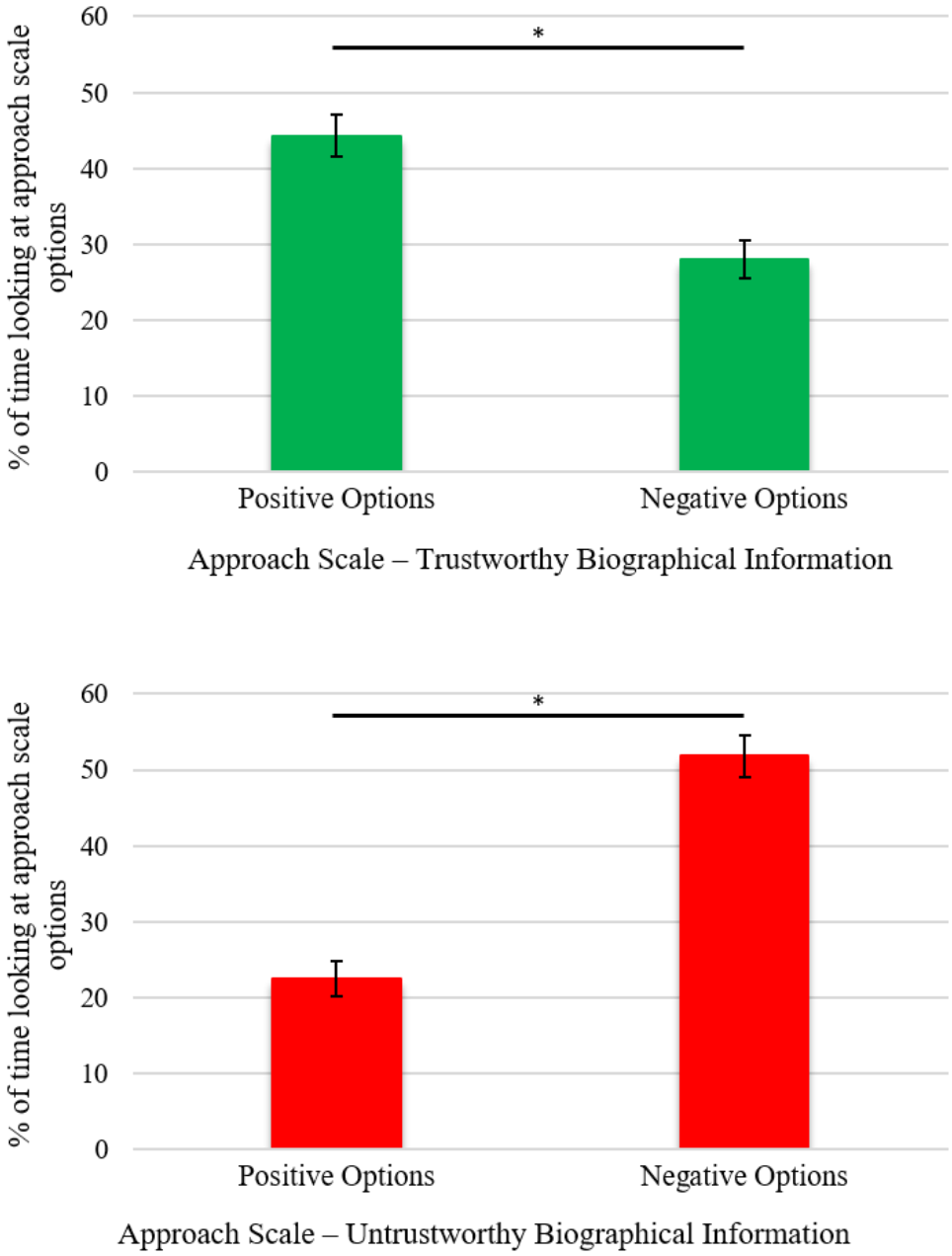

Figure 5. Proportion of time spent looking at approach scale options for faces associated with trustworthy or untrustworthy biographical information across whole sample. Remaining time was spent looking at the 'don't know' option on the approach scale. Error bars represent standard error. * indicates $p<.05$.

Discussion

The present study investigated the influence of biographical information on social approach judgments and visual scanpaths in WS, ASD or SoAD individuals, as well as neurotypical controls by measuring face scanpaths online during a social approach task. To the best of our knowledge, this is the first study to record scanpath data during an approach task. As a result, we also investigated how individuals used relevant non-face information, an approach scale, when making approach judgments.

In line with similar studies that have used emotional expressions to manipulate the presence or absence of social threat (e.g. Frigerio et al., 2006; Kim et al., 2015; Kivity & Huppert, 2016) , WS, ASD, SoAD and neurotypical individuals all demonstrated the expected rank order of approach when presented with faces previously paired with trustworthy, neutral or untrustworthy biographical information This was in line with our prediction. This finding also appears consistent with previous studies in neurotypical individuals where differential amygdala activation to faces associated with positive versus negative biographical information, as well as differences in likeability ratings for faces paired with positive versus negative behaviours are observed (Abdel Rahman, 2011; Charmet-Mougey et al., 2012).

Contrary to our prediction, we did not observe any between-group differences in approach judgments for trustworthy characters, more specifically, the WS group did not judge trustworthy characters to be more approachable than any other group. Also, counter to our predictions, neither the ASD group, nor the SoAD group judged trustworthy characters to be less approachable than the WS or the CA-matched neurotypical group. Taken together, these findings suggest that individuals with WS, ASD and SoAD can use biographical information to make appropriate approach judgments, however, the subsequent judgments may not reflect the everyday social behaviours of individuals with WS, ASD or SoAD. As initially proposed by Porter et al. (2007), it is also possible that this

apparent discrepancy – in the case of WS at least – may be partially underpinned by an online deficit in response inhibition stemming from frontal lobe dysfunction, with WS individuals knowing that unfamiliar people should not be approached and applying this information appropriately in an approach judgment task, but lacking the ability to inhibit their desire to indiscriminately approach others in everyday interactions. The link between response inhibition and approach behaviours has been further elucidated by Little et al. (2013), where response inhibition abilities differentiated approach behaviours in a sample of WS individuals, such that those individuals with the poorest response inhibition abilities rated unfamiliar faces as the most approachable. Moreover, recent findings suggest a link between behavioural inhibition and visual scanpaths in WS, with behavioural inhibition difficulties related to faster attentional capture to the eye region of faces in WS individuals (Boulton et al., 2018c). Taken together, such findings provide further evidence that deficits in inhibition and, more broadly, deficits in executive functioning, may be critically related to the WS social phenotype.

Given the discordance between the approach judgments in the current study and the documented everyday social behaviour of individuals with ASD or SoAD, where social withdrawal and avoidance is common, one may wonder whether frontal lobe dysfunction is implicated in these disorders. Such dysfunction may contribute to cognitive flexibility deficits in ASD, and to heightened behavioural inhibition and cognitive flexibility deficits (for example, getting stuck on anxious thoughts) in SoAD. In ASD, abnormalities in cognitive flexibility and switching have been reported (Corbett, Constantine, Hendren, Rocke, & Ozonoff, 2009), however no research to date has considered how such deficits may contribute to difficulties in daily social interactions. Perhaps individuals with ASD, in a similar vein to those with WS, understand what the ‘correct’ approach judgment for a given face should be, and can apply this knowledge appropriately in an approach judgment task, but experience difficulties shifting their initial behavioural patterns in everyday

interactions, that is, withdrawal due to decreased social motivation. Further, research has found direct evidence of heightened behavioural inhibition in SoAD (Beiderman et al., 2001), which has been linked to social withdrawal and dysfunction in frontal brain regions, such as the orbitofrontal and prefrontal cortices (Fox & Kalin, 2014). As such, while SoAD individuals, like those with WS and ASD, are able to provide the 'correct' approach judgments when presented with faces in an experimental task, their behavioural inhibition, coupled with the tendency to evaluate social stimuli as overly threatening (Wong & Rapee, 2016), may restrict them from applying this knowledge in daily life, subsequently leading to avoidance of social scenarios. It is also possible that due to cognitive flexibility difficulties, individuals with SoAD find themselves 'stuck' on their anxious thoughts (Fujii et al., 2013), further maintaining their anxiety. Future research would benefit from a more direct examination of how executive dysfunction (such as response inhibition and cognitive flexibility deficits) may contribute to the functional social approach abnormalities seen in WS, ASD and SoAD. In particular, looking at the fronto-limbic pathway would be beneficial, given that this network has been implicated in approach and avoidance behaviours in neurotypical individuals (Schlund, Magee, & Hudgins, 2011). Moving beyond isolated brain regions and into neural networks may help understand the complexities that underlie social approach and avoidance in these neurodevelopmental and anxiety conditions.

Previous research looking at face scanpaths and, more specifically, the amount of time spent looking at the eyes in WS, ASD or SoAD has largely taken a disorder-specific approach. Following from Riby and Hancock's earlier studies, where the looking behaviours of WS and ASD individuals were compared (e.g., see Riby and Hancock, 2009a; 2009b), we compared face scanpaths in individuals with WS, ASD or SoAD, as well as neurotypical controls, while on this occasion using neutral faces that had been associated with trustworthy or untrustworthy biographical information. Of note, our

findings did not align with those that have previously manipulated emotional expression to explore visual scanpaths in WS, ASD or SoAD individually. The direct comparison of these disorders, as well as the manipulation of biographical information, led to unexpected findings, both between and within groups.

Counter to our predictions, we did not observe a difference in the overall proportion of time spent looking at the eye region between WS and ASD individuals. Whilst unexpected, given that visual scanpaths were recorded during an active social approach task, unlike previous studies, including Riby and Hancock (2009a; 2009b), which involved passive viewing, it is possible that both WS and ASD individuals used the eye region of faces in a similar manner when making explicit approach judgments. The fact that an explicit instruction can alter eye gaze patterns has potential implications for treatment of increased eye gaze in WS (which can be disconcerting socially) and reduced eye gaze in ASD and SoAD. Namely, initially providing online and explicit instructions and gradually fading this out over time may facilitate automatic eye gaze patterns in WS and ASD individuals that more closely resemble what is seen in neurotypical controls.

Moreover, while we predicted that WS individuals would spend more time looking at the eye region of faces, particularly for untrustworthy characters, when compared to SoAD individuals, the opposite finding was observed. That is, compared to WS individuals, those with SoAD spent significantly *more* time looking at the eye region of untrustworthy characters. Whilst unexpected based on previous findings where emotional expressions have been used as socially positive and socially threatening stimuli, these findings do align with the increased vigilance for threat that contributes to avoidance in SoAD (Wong & Rapee, 2016) and an apparent absence of threat awareness, culminating in impairments in stranger danger awareness, in WS (Riby, Kirk, Hanley & Riby, 2014).

In a similar vein, we predicted that SoAD individuals would spend less time looking at the eye region of untrustworthy characters when compared to neurotypical

controls, in line with the existing literature (Chen & Clarke, 2017), however, our results suggest the opposite pattern. That is, when compared to neurotypical individuals, SoAD individuals spent significantly *more* time looking at the eye region of untrustworthy characters. Although these findings are, at face value, unexpected, recent eye-tracking evidence has found that SoAD individuals display increased overall attention to the eye region of both happy and angry faces relative to neurotypical controls (Boll et al., 2016). Such findings may reflect an increased sensitivity to socially threatening information in SoAD individuals, which contributes to the development and maintenance of social avoidance, aligning with the integrated aetiological and maintenance model of SoAD proposed by Wong and Rapee (2016). Further, it has recently been reported that highly socially anxious individuals show hypervigilance for the eyes of emotional and neutral faces when compared to less socially anxious individuals (Gutierrez-Garcia et al., 2018). This has been proposed as an adaptive strategy that assists in the early detection of threat and rejection, thus allowing for a rapid decision about approach or avoidance in those with SoAD. Given that the current study required participants to complete an approach judgment task while eye movements were recorded, which may have enhanced social anxiety levels and vigilance to threat, it is possible our finding of increased time spent looking at the eyes of untrustworthy characters in SoAD individuals relative to neurotypical controls is reflecting a more sustained vigilance for threat than is seen in passive viewing paradigms, where avoidance of the eyes of threatening expressions is typically observed.

WS individuals spent a similar amount of time looking at the eye region of all faces when compared to neurotypical controls matched on chronological age, however, those with WS were observed to spend significantly more time looking at the eye region of faces in comparison to neurotypical controls matched on mental age. This finding is consistent with earlier findings where emotional expression was manipulated (Porter et al., 2010), but

does not correspond to later findings where more complex mental state expressions were utilised and WS individuals spent less time looking at the eye region in comparison to neurotypical controls matched on chronological or mental age (Hanley et al., 2013). It is possible that the differing stimuli and tasks employed across studies could contribute to the different attention patterns. Further, given that the addition of a cognitive task can alter gaze behaviour via top-down attentional processes (Hayhoe & Ballard, 2005) and, specifically, that high cognitive load can lead to gaze aversion in neurotypical children (Doherty-Sneddon & Phelps, 2005), it is possible that face scanpaths in the MA-matched neurotypical group were affected by the cognitive load associated with making approach judgments for the biographical faces. Further research would benefit from recording eye movements during passive viewing of the biographical faces, as well as during an approach task, in order to more comprehensively tease apart the influence of approach/avoidance decisions on face processing.

Within the clinical groups, striking differences were observed when considering whether time spent looking at the eye region of faces differed depending on the type of biographical information paired with the face. While WS individuals spent more time looking at the eye region of trustworthy characters compared to untrustworthy characters, the opposite pattern was seen in the ASD and SoAD groups, with these individuals spending significantly more time looking at the eye region of untrustworthy characters, relative to trustworthy characters. This dissociation aligns with the prosocial positive bias reported in WS and, likewise, with the social withdrawal and avoidance seen in ASD and SoAD, as well as with the vigilance for threat seen in SoAD. Taken in conjunction with the literature on differential amygdala reactivity in WS, ASD and SoAD (Barak & Feng, 2016; Binelli et al., 2014) and atypical patterns of autonomic arousal (Jarvinen, Ng, Crivelli, Neumann, et al., 2015; Myllyneva et al., 2015) documented in response to manipulation of emotional expressions and gaze direction across these disorders, it would be of interest to

explore whether the manipulation of biographical information elicits similar neurological and physiological differences in people with WS, ASD or SoAD.

On the whole, these visual scanpath findings indicate that manipulating the biographical information associated with a face influences the time spent looking at the eye region across WS, ASD and SoAD individuals when making social approach judgments. The opposing patterns of fixation on the eye region observed for trustworthy and untrustworthy characters within clinical groups provides the first evidence to suggest that biographical information can influence how long individuals look at the eyes and, in contrast to social approach judgements in the current study, seem to correspond well with patterns of everyday social approach/avoidance behaviours across these groups.

As part of our third aim, the current study looked at whether the time spent looking at the approach scale options differed as a function of group and/or biographical information. On the whole, these findings corresponded with the reported approach judgments for biographical faces, with all groups spending more time looking at the positive options on the approach scale for trustworthy characters, and less time looking at the negative options for untrustworthy characters. That all groups appeared to be looking at the approach scale in the same manner, but displayed distinctive scanpath patterns when looking at the eye regions for faces paired with trustworthy compared to untrustworthy biographical information, particularly in the case of the clinical groups, is an interesting finding. It is possible that the decision making process during an online approach task may be similar across individuals with WS, ASD or SoAD, however their face processing strategies, particularly in terms of attention to the eye regions, appear to be different, which may contribute to the social difficulties observed across these disorders.

Strengths, Limitations and Future Directions

The present findings need to be considered within the context of a number of methodological considerations. WS is a rare genetic disorder, which resulted in a small

sample size, however, the resulting participant numbers are comparable to recent studies conducted in this area with this population (Goldman et al., 2016; Hirai et al., 2017), as well as previous cross-disorder comparisons (Jarvinen, Ng, Crivelli, Neumann, et al., 2015; Riby & Hancock, 2009b) . Further, given the increased prevalence of SoAD in females (Asher et al., 2017), we were unable to match participants on sex in the current study, however, all groups were matched on chronological age. Moreover, medium to large effect sizes were observed across findings (Cohen, 1988) despite the limited sample size, highlighting the clinical significance of these findings. Nonetheless, replication of these findings in other individuals with WS, ASD and SoAD would be useful, particularly given that the current study was the first to measure eye movements during a social approach task while manipulating biographical information.

A methodological strength of the current study was the use of a cross-disorder comparison. When investigating conditions with contrasting overt social profiles, cross-disorder comparisons can help to highlight disorder-specific and disorder-shared features of conditions in a way that is difficult when exploring a disorder in isolation. A direct comparison of visual scanpaths to biographical versus emotional faces in these disorders would be of interest, as it would further elucidate face processing mechanisms, and would provide insight as to the differences in face scanpaths and face processing when faces are emotionally salient, or biographically salient. Further, the dissociation we observed in the clinical groups with respect to time spent looking at the eye regions of faces paired with trustworthy or untrustworthy biographical information appears to correspond to the aberrant patterns of amygdala reactivity for emotional expressions seen across these disorders. Consequently, future research is likely to benefit from manipulating biographical information, as a complement to the more frequently used manipulation of emotional expression, across additional methodologies, such as functional neuroimaging and autonomic reactivity, so as to better pinpoint where abnormalities in face processing occur

and how they contribute to the poor social outcomes seen across WS, ASD and SoAD.

Practical Implications.

The present findings indicate that people with WS, ASD or SoAD can learn salient biographical information about neutral faces and can apply this information appropriately when making approach judgments. Given that impairments in everyday social functioning are observed across WS (Elison, Stinton, & Howlin, 2010), ASD (Bauminger, Shulman, & Agam, 2003) and SoAD (Aderka et al., 2012), behavioural therapies, such as social skills training, may benefit from adapting the biographical task used here to assist individuals in developing schemas that can be used to encourage appropriate social interactions, at least for familiar individuals.

In the case of WS for instance, despite being socially vulnerable, WS individuals are unaware of their vulnerability, placing them at increased risk for victimisation (Lough & Fisher, 2016). Further, anecdotally parents tend to report that school-aged children with WS will approach same-aged peers in their school who have previously bullied them, despite their parents asking them to avoid those peers. Therapies that encourage individuals to consider the 'character type' or biographical details known about a familiar person before interacting with them (e.g. whether they are a friend, or someone who has previously wronged them) may not directly increase this awareness of vulnerability within WS individuals, but they may enable WS individuals to develop appropriate schemas about familiar people, which could subsequently influence social approach decisions. On the other hand, applying a similar technique in therapy with ASD or SoAD individuals may help to facilitate social interactions with familiar others; encouraging social engagement with people who are known to be friendly in ASD individuals, and minimising a default decision of social avoidance when there is no evidence to suggest that the person has ill intentions, in SoAD individuals.

Relatedly, our findings suggest that knowing salient biographical information about

a face influences how that face is subsequently attended to, with time spent looking at the eye region differing for trustworthy and untrustworthy characters in all clinical groups. Future interventions may benefit from adapting the biographical task used here in order to modify visual scanpaths for socially positive and socially threatening faces. For instance, given the findings of WS individuals looking more at the eye region of trustworthy characters compared to untrustworthy characters, interventions focused on attending to socially threatening stimuli, as well as socially positive stimuli, may help increase awareness of threat in WS individuals. In contrast, given the increased time spent looking at the eye region of untrustworthy characters relative to trustworthy characters seen in both ASD and SoAD, interventions that prioritise attention to socially positive stimuli, as well as socially threatening stimuli, may go some way to attenuating threat vigilance in these disorders.

Conclusions

The current study indicates that individuals with WS, ASD or SoAD, as well as neurotypical controls, are able to apply biographical information appropriately when making approach judgments. Extending the existing literature, the current findings suggest that face scanpaths are influenced by biographical information in people with WS, ASD or SoAD, in a manner that is largely consistent with their contrasting social phenotypes. While previous studies have manipulated emotional expressions when looking at approach judgments or visual scanpaths in each disorder, this is the first study to manipulate biographical information to explore visual scanpaths during an approach task, rather than passive viewing, whilst directly comparing WS, ASD and SoAD. These findings highlight the importance of conducting direct comparisons across disorders characterised by starkly contrasting social phenotypes, in order to contribute to our broader understanding of social behaviour.

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General Discussion

Successful social behaviour is complex, requiring us to process multiple pieces of information in a specific manner. Who we allocate our attention to, our ability to rapidly recognise emotions in others, how we look at faces when interacting with people, and our decisions of who to approach or, conversely, who to avoid, are all critical elements of social processing. This thesis aimed to extend our understanding of social processing in WS, ASD and SoAD by exploring the influence of biographical information on attention allocation, emotion recognition, the salience of certain face regions and approach/avoidance decisions. Previous research in these populations had only used perceptual (emotional stimuli) and not biographical stimuli (information about the character type of a given person). Therefore, to ascertain whether biographical information influenced social processing in a similar manner to perceptual or emotional information, biographical face stimuli were used in place of emotional face stimuli. Moreover, these three clinical populations had not been directly compared in the past. This thesis used a cross-disorder comparison in order to better understand abnormalities in social processing in conditions which present with contrasting social profiles. The thesis comprised five major works across Papers 1 to 5, utilising experimental tasks that have previously been used in research with WS, ASD or SoAD individuals, namely, a dot-probe paradigm, an emotion recognition task, an eye-tracking task and a social approach judgment task. On the whole, the findings presented across this thesis suggest that biographical information influences social processing in WS, ASD and SoAD individuals, largely in the direction that one would predict based on their divergent social profiles.

Findings and Implications of Individual Papers

Paper 1

Consistent with predictions and building on the findings of Dodd and Porter (2010), Paper 1 revealed that WS individuals demonstrated an attention bias for trustworthy biographical faces relative to neurotypical controls. This finding provided indirect

evidence for the role of the amygdala in processing biographical information, as the attentional bias for happy faces seen in WS is thought to reflect an attentional correlate of amygdala dysfunction (Dodd & Porter, 2010; Haas et al., 2009). When considered in light of prior research in neurotypical individuals, where differential amygdala activation has been observed in response to faces paired with positive or negative biographical information (Charmet-Mougey et al., 2012), this finding suggests that the established amygdala dysfunction for emotional faces in WS individuals may extend to face stimuli that are perceptually neutral, but biographically salient.

Counter to both the predictions of Paper 1 and the proposal put forth by Riby et al., (2011), there was no evidence that the attention bias towards trustworthy biographical faces in WS individuals was driven by attentional disengagement difficulties. However, a within-group analysis of the trustworthy bias in WS individuals revealed considerable heterogeneity; some WS individuals displayed attentional capture effects, while others displayed attentional disengagement effects. This finding speaks to the heterogeneity observed across WS and other neurodevelopmental disorders and highlights the importance of fine-grained, within-group analyses. Relatedly, while Paper 1 found some evidence for a relationship between attention biases and IQ as proposed by McGrath et al. (2016), individual heterogeneity across samples may, at least partially, explain the divergent findings.

Paper 2

Building on findings from Paper 1, the attention bias for trustworthy biographical faces in WS individuals was larger than that seen in ASD and SoAD individuals. Moreover, consistent with the predictions of Paper 2 and in line with the social motivation theory of ASD (Chevallier et al., 2012), ASD individuals did not display an attention bias for either trustworthy or untrustworthy biographical faces and also displayed smaller fluctuations in their attention bias for trustworthy biographical faces. As hypothesised,

individuals with SoAD demonstrated an attention bias for untrustworthy biographical faces in line with theoretical explanations of SoAD, where a vigilance for social threat is thought to assist in maintaining social anxiety (Wong & Rapee, 2016). For WS and SoAD individuals, these findings may provide indirect support for the role of the amygdala in processing biographical information given that the attentional patterns for biographical faces largely mirror the amygdala reactivity seen for emotional faces in these groups (increased reactivity to happy faces in WS and angry faces in SoAD). Moreover, these results highlight that attention allocation for biographical faces in WS, ASD and SoAD largely corresponds to the social profiles seen across these conditions, namely, increased attention for positive social stimuli in WS, decreased attention for social stimuli irrespective of the valance in ASD, and increased attention for threatening social stimuli in SoAD.

Paper 3

In Paper 3, counter to predictions, biographical information did not influence emotion recognition accuracy rates, nor the type of misclassifications made. However, while overall accuracy rates across all groups were high, there were some unexpected group differences. Counter to both the predictions of Paper 3 and prior research (Gagliardi et al., 2003), accuracy rates in WS individuals were higher than those seen in MA-matched neurotypical controls. Further, utilising a cross-disorder comparison revealed some interesting similarities between conditions, as well providing further support for established differences. Whilst ASD individuals displayed higher accuracy rates for neutral expressions compared to WS individuals in line with findings from Jarvinen, Ng, Crivelli, Neumann, et al. (2015), counter to predictions, accuracy rates for angry expressions were similar between clinical groups.

Counter to predictions, neither ASD nor SoAD individuals displayed a tendency to misclassify neutral expressions as angry. This finding is also inconsistent with accounts of

a negative interpretation bias in these groups (Eack et al., 2015; Peschard & Philippot, 2017). However, there was some evidence of a positive interpretation bias in the WS group, with a subset of WS individuals more frequently misclassifying neutral faces as happy, suggesting that the positive bias reported in WS at the neurological (Haas et al., 2009), physiological (Jarvinen, Ng, Crivelli, Arnold, et al., 2015), attentional (Goldman et al., 2016) and cognitive (Godbee & Porter, 2013) levels may also occur during the perception of expressions for some individuals with WS.

When considered in the context of other findings within this thesis, as well as with prior research in neurotypical individuals (Lazerus et al., 2016), a possible explanation for the lack of influence of biographical information on emotion recognition may lie in the type of evaluations influenced by biographical information. It is likely that biographical information influences evaluations that are directly relevant for social interactions, such as approach judgments, rather than influencing the direct perception of emotional expressions.

Paper 4

While Papers 1 and 2 examined social processing using a dot-probe paradigm to measure attentional biases (including attentional capture and disengagement), Paper 4 utilised an eye-tracking paradigm to measure overall attention to salient and non-salient face regions, as well as attentional capture and disengagement from the eye region of biographical faces. Somewhat consistent with predictions, Paper 4 indicated that WS individuals spent more time looking at salient face features in comparison to MA-matched neurotypical controls. This finding is also in line with predictions made by the social salience hypothesis (Frigerio et al., 2006). However, no differences in time spent looking at salient face features were observed between the clinical groups, nor did ASD or SoAD individuals spend less time looking at salient face features relative to neurotypical controls, counter to expectations based on the social motivation theory of ASD and the avoidance of

threatening faces generally observed in SoAD individuals when faces are displayed for longer periods (Chen & Clarke, 2017).

Considering initial attention patterns to the eye region, specifically attentional capture and attentional disengagement, Paper 4 revealed that WS individuals displayed difficulties disengaging their attention from the eye region of all biographical faces compared to MA-matched neurotypical controls, consistent with both the predictions of Paper 4 and those of Riby et al., (2011), where increased face salience in WS is thought to be underpinned by difficulties disengaging attention from faces. Moreover, compared to ASD individuals, WS individuals demonstrated difficulties disengaging their attention from the eye region of trustworthy biographical faces, which may correspond to the increased interest in faces and more specifically the eyes, seen in WS, alongside the decreased interest in faces commented on in ASD. Moreover, within-group differences were observed in the WS group, such that individuals with WS took longer to disengage their attention from trustworthy biographical faces as compared to neutral or untrustworthy biographical faces. These findings extend the original predictions of Riby et al. (2011), suggesting that, for WS individuals, attentional disengagement difficulties may be particularly pronounced when individuals are required to draw their attention away from the eye region of positive faces.

As predicted, and in line with the social motivation theory of ASD, individuals with ASD did not show any evidence of attentional capture towards the eye region of face. However, faster disengagement from the eye region of faces was not observed in the ASD group relative to any other group, failing to support predictions of the eye avoidance hypothesis (Tanaka & Sung, 2016). Finally, partially consistent with predictions, SoAD individuals displayed faster attentional capture to the eye region of all biographical faces compared to neurotypical controls, but did not display any disengagement difficulties relative to any other group, partially supporting predictions of attentional control theory

(Eysenck et al., 2007).

When comparing relationships between executive functioning and initial patterns of visual attention, an interesting pattern of findings was revealed. WS, ASD and SoAD individuals displayed executive functioning difficulties which were differentially related to attentional capture and attentional disengagement. Whilst the profile of executive functioning difficulties differed somewhat between groups, there were notable similarities, particularly in the domain of shifting. This finding provides indirect support for frontal lobe dysfunction across WS, ASD and SoAD, given that executive functions are thought to be subserved by the frontal lobes (Miyake et al., 2000).

Taken together, these results suggest that visual attention to the eye region of faces differs between WS, ASD and SoAD individuals, largely in ways that one might expect based on their social profiles. Further, these atypicalities in visual attention to the eye region appear to be related to executive functioning difficulties in each condition, suggesting that frontal lobe dysfunction may represent a common neural substrate for the divergent social processing abnormalities seen in WS, ASD and SoAD.

Paper 5

While Paper 4 considered early attentional mechanisms that may be linked to social processing, specifically, attentional capture and disengagement, Paper 5 extended upon these findings, by looking at social approach judgments to biographical faces in WS, ASD and SoAD, as well as the overall time spent looking at the eye region and social approach rating scale for these biographical faces. Measuring social processing directly using a social approach task in Paper 5 revealed that WS, ASD, SoAD and neurotypical individuals provided comparable social approach judgments that were influenced by the biographical information paired with the face. Counter to predictions, there were no group differences in approach judgments for trustworthy, neutral or untrustworthy biographical faces, suggesting that all individuals were able to learn salient biographical information

about neutral faces and apply this knowledge appropriately in a social approach task.

In contrast to the above findings, measuring social processing indirectly using eye-tracking revealed a dissociation within the clinical groups. While WS individuals spent more time looking at the eyes of trustworthy (relative to untrustworthy) biographical faces, ASD and SoAD individuals spent more time looking at the eyes of untrustworthy (relative to trustworthy) biographical faces. No such findings were observed in the neurotypical groups, suggesting that these differences may be related to the social processing difficulties seen across WS, ASD and SoAD. It is possible that this divergent pattern of findings when using direct and indirect measures is attributable to a dissociation between knowing how to interact in a social situation, and how one actually interacts during a social situation ('knowing' versus 'doing'; see, Porter, Coltheart, and Landon, 2007), which may be occurring secondary to frontal lobe dysfunction.

Moreover, while the social approach judgments reported in Paper 5 fail to support predictions of amygdala dysfunction in WS, ASD and SoAD, where abnormal approach judgments would be expected given the role of the amygdala in approach and avoidance decisions, the face scanpath findings in Paper 5 could be interpreted as providing indirect support for amygdala dysfunction across WS, ASD and SoAD, particularly given the noted role of the amygdala in allocating attention to the eye region of faces (Adolphs, 2010). Increased time spent looking at the eye region of trustworthy biographical faces in WS may correspond to the increased amygdala reactivity for happy faces seen in this group (Haas et al., 2009), while increased time spent looking at the eye region of untrustworthy biographical faces in ASD and SoAD may correspond to the increased amygdala reactivity for threatening faces seen in these conditions (Gentili et al., 2016; Tottenham et al., 2014).

Broader Contributions of Thesis

Each of the five papers included in this thesis addressed independent research questions. However, when interpreted together, the findings of these five papers have made

a number of significant contributions to the field. These contributions are discussed below.

Understanding Social Processing Using Multiple Methods

The papers presented within this thesis investigated social processing using a combination of direct (emotion recognition, social approach judgments) and indirect (attentional biases, visual attention to the eye region) methods. Applying the same biographical paradigm to both direct and indirect methods provided a greater understanding than using a single method alone. For instance, while there was no apparent influence of biographical information on emotion recognition ability (measured using a direct emotion recognition task in Paper 3), for WS and SoAD individuals, there was a clear influence of biographical information on attentional biases (measured using an indirect dot-probe task in Papers 1 and 2). Moreover, across WS, ASD and SoAD individuals, using a combination of direct and indirect methods concurrently, such as social approach judgments and face scanpaths (both measured in Paper 5), revealed a disparate pattern of results. These findings suggest that the complex social processing abnormalities observed in conditions such as WS, ASD and SoAD might be best understood using multiple methods, from direct, explicit approach judgment paradigms to indirect, implicit dot-probe paradigms.

Similarly, utilising multiple indirect methods helped to elucidate social processing within a single group. While attentional disengagement difficulties, proposed by Riby et al. (2011) to underlie the increased face salience in WS individuals, were not observed within the WS group when using a dot-probe paradigm (Papers 1 and 2), this pattern of disengagement difficulties was revealed when an eye-tracking paradigm was utilised, and specifically when attention to the eyes was taken into account (Paper 4). Taken together, these findings suggest that exploring a specific aspect of social processing using a single method can limit one's understanding of how additional aspects of social processing can be similarly, or differentially, affected. Utilising the same biographical task across multiple

methods with the same sample of participants may also help to reveal the measurement constraints of certain methodologies. Indeed, the reliability of the dot-probe paradigm has been contested within the literature (Price et al., 2015) and measurements of attentional bias that are generated from dot-probe tasks do not necessarily correlate with indices from eye-tracking paradigms (Waechter et al., 2013). Utilising multiple methods may thus be beneficial both from a practical perspective, to further understand social processing difficulties in conditions such as WS, ASD and SoAD, but also from an experimental design perspective, to better understand the parameters of a given methodology. As can be ascertained from the findings throughout Papers 1 to 5, the use of both direct and indirect methods to explore social processing in this thesis provided an in-depth understanding of the differential social processing impairments across individuals with WS, ASD or SoAD.

The Benefits of Cross-Disorder Comparisons

The majority of research has investigated social processing by comparing a clinical condition to a single comparison group, often comprised of neurotypical controls. The papers within the current thesis adopted a cross-disorder comparison to investigate social processing. By selecting conditions featuring distinct social profiles, an interesting pattern of similarities and differences in social processing abilities emerged.

While WS, ASD and SoAD feature distinct social profiles, this thesis revealed two key similarities between conditions, namely, certain aspects of executive functioning difficulties and social approach judgements. First, Paper 4 indicated that executive functioning difficulties are common across these conditions. Specifically, when looking at group averages, individuals with WS, ASD or SoAD all displayed impairments in cognitive flexibility. Such a finding has important contributions when considered in the context of broader social functioning. Everyday social interactions require substantial cognitive flexibility, for instance, switching between conversational topics, so, it may be unsurprising that for individuals with WS, ASD or SoAD, where social interactions are

navigated with difficulties, breakdowns in this component of executive functioning occur. Second, Paper 5 revealed that WS, ASD and SoAD individuals displayed similar social approach judgments for biographical faces and these approach judgments were, in turn, similar to neurotypical controls. This finding does not align with what one would expect based on the contrasting social profiles of WS, ASD and SoAD and, as mentioned above, may point to a dissociation between knowing how one should behave in social situations compared to how one actually behaves in social situations. Taken together, these similarities suggest that a common neural substrate, such as frontal lobe dysfunction, may underlie some of the social processing impairments across WS, ASD and SoAD.

Whilst the use of a cross-disorder comparison elucidated certain similarities between WS, ASD and SoAD, direct comparisons of conditions featuring opposing social profiles can also elucidate differences in social processing that may not be revealed by comparing a single condition to neurotypical controls. For example, Paper 5 revealed a dissociation in face scanpaths (specifically, the amount of time spent looking at the eye region of trustworthy and untrustworthy biographical faces) between WS, ASD and SoAD individuals, which largely aligned with the social profiles of each condition, tentatively and indirectly suggesting a role for the amygdala in processing biographical information in these conditions. On the whole, the findings from this thesis suggest that our understanding of social processing abnormalities within a single condition can be deepened through comparisons with conditions featuring contrasting social processing abnormalities, in addition to comparisons with neurotypical controls.

Finally, the direct comparison of WS, ASD and SoAD individuals allowed for the evaluation of different accounts of social processing, from the social salience hypothesis in WS, to the social motivation theory of ASD and the increased attention for social threat proposed by cognitive-behavioural models of SoAD. When evaluating these accounts side by side in the context of a cross-disorder comparison, certain similarities between accounts

became apparent. For instance, where the social salience hypothesis of WS posits that an increased interest in people and faces gives rise to the increased sociability seen in WS (Frigerio et al., 2006), the social motivation theory of ASD proposes that the social withdrawal characteristic of ASD individuals stems from a decreased interest in people and faces (Chevallier et al., 2012). Meanwhile, cognitive-behavioural models of SoAD suggest that individuals with SoAD ascribe an increased salience value specifically to threatening social stimuli (such as angry faces) which, in turn, serves to maintain their anxiety and fear of negative evaluation (Rapee & Heimberg, 1997; Wong & Rapee, 2016). Taken together, it appears as though these accounts are explaining a similar social processing anomaly, that is, salience for people and faces, but each account only considers how this anomaly applies to a single condition. Perhaps a more unified account which encompasses this unusual salience for faces across multiple conditions, from increased salience in WS, to decreased salience in ASD and increased salience specifically for threat in SoAD would provide a clearer framework for social processing across different conditions.

Using Biographical Information to Explore Social Processing in WS, ASD and SoAD

Much of the research that has contributed to our understanding of social processing abnormalities in WS, ASD or SoAD has typically manipulated the level of social threat or social positivity by using different emotional expressions (e.g., see Jarvinen et al., 2015; Kivity & Huppert, 2016; Uljarevic & Hamilton, 2013) . A novel contribution of the present thesis was to use biographical information as a way of manipulating the presence or absence of social threat and subsequently compare and contrast elements of social processing in individuals with WS, ASD or SoAD. On the whole, the findings in this thesis converge with previous findings where emotional expressions have been used, suggesting that WS, ASD, SoAD and neurotypical individuals are able to learn salient biographical information about perceptually neutral faces and that this biographical information influences both direct (social approach judgements) and indirect (attention biases, face

scanpaths) measures of social processing.

A major finding in this thesis was that biographical information can influence social processing in similar ways to emotional stimuli in WS, ASD and SoAD. We often have to rely on the information we already know about a person, or, in the case of strangers, form an impression based on existing schemas, in order to make social decisions, so it makes sense that biographical information affects our social processing in this manner. Whilst the biographical paradigm utilised in the present thesis could be modified to improve its ecological validity, it nonetheless contributes to our understanding of how we may measure social processing using paradigms that more closely resemble real-life social situations.

Limitations and Future Directions

As discussed, this thesis has made a number of novel contributions to the field. However, there are some limitations and unanswered questions that have arisen from the papers presented within this thesis. Perhaps the most notable limitation of the studies presented in this thesis is the small sample size, coupled with the broad age range of participants. Given the rarity of WS, it can be difficult to accrue large samples and it should be noted that the sample size across the papers within this thesis is comparable to recent studies with WS individuals (Goldman et al., 2016; Hirai et al., 2017). However, given this small sample size, the generalisability of these findings to the broader WS, ASD and SoAD populations is limited. Replication of these findings using larger samples would provide a more in-depth understanding of the influence of biographical information on social processing. Moreover, given the novelty of the biographical paradigm and the attentional demands of some of the tasks throughout this thesis, only adolescents and adults with WS, ASD or SoAD were included in this thesis. Extending these findings by looking separately at more narrowly defined age ranges, for instance, primary and high-school aged children or adults, would provide a clearer understanding of social processing in WS, ASD

and SoAD across the lifespan.

Another limitation of the present thesis is that the diagnoses in the ASD group were not formally confirmed using a gold standard diagnostic measure, such as the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2012). The rationale for this was based on recent findings which call into question the suitability of the ADOS for use in ASD adults without intellectual disabilities (Baghdadli, Russet, & Mottron, 2017), as well as practical considerations given the testing time already required of participants for the experimental tasks. Moreover, ASD individuals completed well-validated screening measures, met criteria for ASD according to the DSM-5 criteria (American Psychiatric Association, 2013) and had previously received a diagnosis from a clinical psychologist, making it unlikely that individuals would have misreported their diagnoses.

Relatedly, the studies presented across this thesis did not use a gold standard measure, such as the ADIS, to check for a clinical diagnosis of SoAD in the ASD group. The rationale for this was that, while social anxiety is commonly seen in ASD, the qualitative experiences of social anxiety are quite different between ASD individuals and typically developing individuals with SoAD (Bejerot et al., 2014), with some authors questioning which measures are best suited to assess SoAD in ASD (Tyson & Cruess, 2012). Further, specifically recruiting a sample of ASD individuals without SoAD would result in an ASD group that is not representative of ASD overall, given the high comorbidity of SoAD in ASD (Spain, Sin, Linder, McMahon, & Happé, 2018). In order to disentangle subtle social processing differences between ASD and SoAD, future research would benefit from comparing and contrasting individuals with ASD only, individuals with ASD and co-morbid SoAD, as well as individuals with SoAD only.

Finally, it should be acknowledged that the papers within this thesis have investigated social processing in a sample of individuals with high-functioning ASD, somewhat limiting the generalisability of these findings. Intellectual disability often co-

occurs with ASD (Matson & Shoemaker, 2009) and, as noted by Plesa Skwerer (2017) nonverbal or minimally verbal individuals account for approximately 30% of all ASD cases, however, research has largely failed to address social functioning in this specific subgroup. While the biographical paradigm utilised throughout this thesis would likely be difficult to administer to minimally verbal or nonverbal ASD individuals, it may be suitable for ASD individuals with intellectual disabilities, given that it was appropriate for use in WS individuals, where an intellectual disability was present. Extending the findings from the present thesis by including a group of ASD individuals with intellectual disability would provide a more generalisable picture of social functioning across the whole spectrum of individuals with ASD.

The findings presented across the five papers in this thesis demonstrated that biographical information can influence social processing in WS, ASD and SoAD individuals. Given that the present thesis addressed attentional and behavioural correlates of social processing, future research would benefit from an investigation of the neurological correlates of social processing, specifically, whether biographical information influences abnormal reactivity in brain regions known to be involved in social processing, such as the amygdala and frontal lobes. More specifically, in an effort to build on the findings presented across this thesis, future research would benefit from the simultaneous measurement of neuroimaging and eye-tracking. Given that WS individuals experience difficulties disengaging attention from eye regions (Riby et al., 2011), while ASD and SoAD individuals tend to avoid eye contact (Chen & Clarke, 2017; Tanaka & Sung, 2016), it would be of interest to explore differential neural reactivity, particularly within the amygdala, in response to looking at the eye regions of biographical faces. In a related vein, given the discordance observed between approach judgments and face scanpaths across WS, ASD and SoAD individuals in Paper 5, conducting a social approach judgment task during neuroimaging would elucidate the role of frontal lobe dysfunction during social

approach decisions in individuals with these conditions. Finally, future neuroimaging research across WS, ASD and SoAD would benefit from an investigation of neural networks, particularly frontal-amygdala connectivity, to further inform our understanding of social processing impairments across these groups.

An understanding of *where* breakdowns in social processing occur (for example, by investigating behavioural and neurological correlates) is important, but improving social outcomes for individuals with WS, ASD or SoAD requires an integrated understanding of *how* these breakdowns contribute to social interaction difficulties and pervasive social dysfunction. To this end, future research would benefit from the use of longitudinal designs to more clearly demarcate the factors that contribute to social dysfunction across development.

Relatedly, while WS, ASD and SoAD are conditions featuring distinct social profiles, individuals with these conditions display similar difficulties in everyday social functioning. Diminished interpersonal relationships, increased feelings of loneliness and poor mental health outcomes are observed across all conditions (Aderka et al., 2012; Jawaid et al., 2012). In addition to looking at the neurological underpinnings of social processing across these conditions, future research would benefit from exploring functional social outcomes and behaviours, such as everyday social approach and avoidance behaviours. Interpreted alongside neurological findings, such research would provide a more comprehensive understanding of how breakdowns at the neurological level can have cascading effects on social processing and, ultimately, on social functioning.

Although cross-disorder comparisons can enhance our understanding of abnormalities in a single condition and can elucidate qualitative differences between conditions, the value of within-disorder comparisons should not be overlooked. As stated by Tager-Flusberg, Plesa Skwerer, and Joseph (2006, p. 179), “we are likely to learn as much or more from a fine-grained analysis of within syndrome variation as we have done

from comparing one syndrome to another or to well-matched controls". Thus, in addition to utilising cross-disorder comparisons to better identify differences in social behaviour between conditions, future studies should also take within-disorder heterogeneity into consideration, in an effort to identify individual differences in social processing and design interventions that are tailored to target the specific needs of an individual. Given the large samples necessary for such investigations, future research would benefit from collaborative, multi-site studies.

Social interactions are fluid and dynamic, requiring our social processing abilities to be flexible and adaptable to change. Laboratory-based, experimental tasks involving the presentation of static faces on computer screens do not account for the complexities inherent in everyday social interactions. During an online social interaction, we must maintain a constant awareness of the other person. Where they look, the movements they make and, as this thesis has demonstrated, the biographical information we know about them, all play a part in influencing our social interactions and decisions. Therefore, while the findings of this thesis provide important knowledge about the role of biographical information on social processing, there is a need for future research to develop more ecologically valid paradigms to deepen our understanding of the complexities of social processing. Developing experimental paradigms which make use of virtual reality technologies may address some of these issues by more closely approximating real-life social situations whilst still providing researchers with experimental control.

Finally, from a clinical perspective, it is possible that the biographical paradigm used in the current thesis could be adapted for use in social skills training and cognitive behavioural therapy with these individuals. Encouraging WS, ASD or SoAD individuals to think about the biographical details known about a familiar person during social interactions may help to build schemas about familiar people (for instance, whether they are a friend or foe). Over time, such a treatment strategy could help individuals make more

considered decisions that ultimately lead to more adaptive social outcomes.

Concluding Remarks

The five papers presented in this thesis investigated the influence of biographical information on social processing in individuals with WS, ASD or SoAD. The principal findings revealed by this thesis can be summarised as follows: 1) Biographical information influenced how attention was allocated to faces across individuals with WS, ASD or SoAD, with WS individuals displaying an attention bias for trustworthy (compared to untrustworthy) biographical faces and SoAD individuals displaying an attention bias for untrustworthy (compared to trustworthy) biographical faces; 2) Biographical information influenced the amount of time spent looking at the eye region of faces, such that WS individuals spent more time looking at the eyes of trustworthy (compared to untrustworthy) biographical faces and experienced difficulties disengaging their attention from these faces, while ASD and SoAD individuals spent more time looking at the eyes of untrustworthy (compared to trustworthy) biographical faces; 3) While biographical information did not influence the direct perception of emotional expressions in WS, ASD or SoAD, some WS individuals showed evidence of a positive interpretation bias when identifying neutral expressions; and 4) For WS, ASD and SoAD individuals, biographical information influenced social approach judgments, however in a manner that would not be expected based on their distinct social profiles.

Taken together, this thesis suggests that for WS, ASD and SoAD individuals, biographical information influences indirect elements of social processing, including attention allocation, as well as direct elements of social processing, such as social approach judgments. The findings presented within this thesis provide important preliminary evidence of how biographical information may influence social processing in disorders characterised by distinct social profiles.

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Ethics Approval

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5 March 2014

Dr Melanie Porter
Department of Psychology
Faculty of Human Sciences
Macquarie University NSW 2109

Dear Dr Porter

RE: *The role of oxytocin in modulating anxiety and social behaviour in neurodevelopmental and anxiety disorders*

Thank you for submitting the above application for ethical and scientific review. Your application was first considered by the Macquarie University Human Research Ethics Committee (HREC (Medical Sciences)) at its meeting held on 28 November 2013 and the Scientific Sub-Committee (SSC) out of session.

The HREC (Medical Sciences) and SSC requested clarifications/modifications to the above project, and advised that your responses would be reviewed by the HREC (Medical Sciences).

Your response was received on 19 February 2014 and considered at the HREC (Medical Sciences) meeting held on 27 February 2014.

I am pleased to advise that ethical and scientific approval has been granted for this project to be conducted at:

- Macquarie University

This research meets the requirements set out in the *National Statement on Ethical Conduct in Human Research* (2007) (the *National Statement*).

This letter constitutes ethical and scientific approval only.

Details of this approval are as follows:

Reference No: 5201300854

Approval Date: 27 February 2014

The following documentation has been reviewed and approved by the HREC (Medical Sciences):

Documents reviewed	Version	Date
Macquarie University Ethics Application Form	2.3	July, 2013
Correspondence from Dr Melanie Porter providing additional information for ethics application REF 5201300854		dated 10/01/2014

Macquarie University Participant Information and Consent Form (Parent/Guardian – Patient Populations: All clinical participants under 18 and for all Williams Syndrome and Autistic participants)	2	February 2014
Macquarie University Parent Information and Consent Form (child ASD and child SAD participants) entitled *The role of oxytocin in modulating anxiety and social behaviour in Williams Syndrome, Autism and Social Anxiety Disorder*	2	February 2014
Macquarie University Parent Information and Consent Form (Adult ASD and Adult SAD participants) entitled *The role of oxytocin in modulating anxiety and social behaviour in Williams Syndrome, Autism and Social Anxiety Disorder*	2	February 2014
Macquarie University Parent Information and Consent Form (WS participants) entitled *The role of oxytocin in modulating anxiety and social behaviour in Williams Syndrome, Autism and Social Anxiety Disorder*		
Macquarie University Participant Information and Consent Form (Neurotypical Adults – Pilot study) Entitled *The role of anxiety and social behaviour in neurodevelopmental and anxiety disorders*	1	February 2014
Macquarie University Participant Information and Consent Form (Neurotypical Children – Pilot study) Entitled *The role of anxiety and social behaviour in neurodevelopmental and anxiety disorders*	1	February 2014
Method for modified version of biographical face learning task		
Neuronauts advertisements		
Email to send to families after responding to Neuronauts advert		
Advert for SONA/MACCS subject pool		
Email to send to staff members from Department of Psychology and Department of Cognitive Science		
Shyness Questionnaire – Eisenberg et al (1995) adapted from Grossenbacher, Rothbart and Derryberry (1988)		
Vineland II, ADI S, Desire for future Interaction Questionnaire, DASS 21, SIAS-6 and SPS-6		

Please ensure that in all future correspondence with the HREC all documentation includes a version number and date.

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Standard Conditions of Approval:

1. Continuing compliance with the requirements of the *National Statement,* which is available at the following website:

http://www.nhmrc.gov.au/book/national-statement-ethical-conduct-human-research

2. This approval is valid for five (5) years, subject to the submission of annual reports. Please submit your reports on the anniversary of the approval for this protocol.

3. All adverse events, including events which might affect the continued ethical and scientific acceptability of the project, must be reported to the HREC within 72 hours.

4. Proposed changes to the protocol must be submitted to the Committee for approval before implementation.

It is the responsibility of the principal investigator to retain a copy of all documentation related to this project and to forward a copy of this approval letter to all personnel listed on the project.

Should you have any queries regarding your project, please contact the Ethics Secretariat on 9850 4194 or by email ethics.secretariat@mq.edu.au

The HREC (Medical Sciences) Terms of Reference and Standard Operating Procedures are available from the Research Office website at:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics

The HREC (Medical Sciences) wishes you every success in your research.

Yours sincerely

Professor Tony Eyers
Chair, Macquarie University Human Research Ethics Committee (Medical Sciences)

This HREC is constituted and operates in accordance with the National Health and Medical Research Council's (NHMRC) *National Statement on Ethical Conduct in Human Research* (2007) and the *CPMP/ICH Note for Guidance on Good Clinical Practice.*