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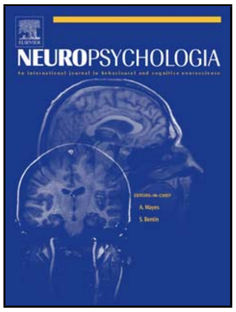

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Impaired recognition of emotions from body movements is associated with elevated motion coherence thresholds in autism spectrum disorders

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Abstract

Recent research has confirmed that individuals with Autism Spectrum Disorder (ASD) have difficulties in recognizing emotions from body movements. Difficulties in perceiving coherent motion are also common in ASD. Yet it is unknown whether these two impairments are related. **Thirteen adults** with ASD and 16 age- and IQ-matched typically developing (TD) adults classified basic emotions from point-light and full-light displays of body movements and discriminated the direction of coherent motion in random-dot kinematograms. The ASD group was reliably less accurate in classifying emotions regardless of stimulus display type, and in perceiving coherent motion. As predicted, ASD individuals with higher motion coherence thresholds were less accurate in classifying emotions from body movements, especially in the point-light displays; this relationship was not evident for the TD group. The results are discussed in relation to recent models of biological motion processing and known abnormalities in the neural substrates of motion and social perception in ASD.

Keywords: autism; biological motion; body movement; emotion; motion coherence

Impaired recognition of emotions from body movements is associated with elevated motion coherence thresholds in autism spectrum disorders

There are numerous reports of individuals with Autism Spectrum Disorders (ASD) being impaired in recognizing emotions from static faces (e.g., Ashwin et al., 2006; Hobson et al., 1988; reviewed by Pelphrey et al., 2002). Three studies have shown that individuals with ASD are also impaired, relative to comparison individuals without autism, in recognizing emotions from body movements, whether they are asked to describe or name intended expressions from point-light displays[1] (Hubert et al., 2007; Moore et al., 1997) or to label, in a forced-choice task, the intended emotion represented in full-light displays[1] (Philip et al., submitted). The latter study found that the same ASD group was also impaired in identifying facial and vocal expressions of basic emotions.

One reason why individuals with ASD might have difficulties in recognizing emotions in others is as a consequence of deficits in ‘theory of mind’, which are characteristic of ASD (e.g., Baron-Cohen, 1995; Perner et al., 1989). A theory of mind deficit is consistent with the cross-modal emotion recognition deficit reported by Philip et al. (submitted). Yet ASD has also been associated with atypical motion perception (for reviews, see Dakin & Frith, 2005; Milne et al., 2005), especially impairments on tasks that rely on relatively global or complex motion signals, such as detecting rigid, translational coherent motion in random-dot kinematograms (Milne et al., 2002; Milne et al., 2006; Pellicano et al., 2005; Spencer et al., 2000), albeit with some exceptions (Del Viva et al., 2006; Milne et al., 2006; Tsermentseli et al., 2008). Point-light human body motion is another case of relatively global, complex motion, yet evidence for impaired detection of such motion is less clear, with one study showing impaired detection accuracy (Blake et al., 2003) but two studies showing no effect on accuracy (Freitag et al., 2008; Herrington et al., 2007), one of which nevertheless showed longer detection reaction times in ASD individuals (Freitag et al., 2008). Moreover, evidence to date suggests that accuracy in *identifying* everyday, non-emotional actions from point-light displays is not compromised in ASD (Hubert et al., 2007; Moore et al., 1997), **although this has not yet been tested in a forced-choice paradigm**.

Might impaired recognition of emotions from body movements be attributable at least in part to atypical visual motion processing, as opposed to being an entirely higher-level deficit in attributing emotions or mental states more generally? In order to address this question, the present study assessed the abilities of ASD and typically developing individuals to classify emotional expressions from body movements and to discriminate translational coherent motion in random-dot kinematograms. The logic was as follows. Successful discrimination of the direction of the coherently moving dots cannot be achieved on the basis of the motion of one or a small number of adjacent dots, but rather, requires integration of motion signals across a larger area. Motion coherence deficits – specifically, higher motion coherence thresholds – are prevalent (if not universal) in ASD. **Successful recognition of bodily expressed emotions depends on the kinematics of body or body-part movement (Pollick et al., 2001; Roether et al., 2008) as well as on changes in body form over time (Atkinson et al., 2007b). The perception of bodily kinematics and of changes in body form over time** cannot be achieved on the basis of local image motion and, especially in point-light displays, relies on the ability to perceive coherent motion. It was therefore predicted that, to the extent that ASD individuals would be impaired in their ability to discriminate simple coherent motion, they would also be impaired in their ability to recognize emotions from body movements.

While bodily kinematics also provide important cues for the perception of biological motion per se, especially gait, and for judging certain person characteristics such as sex and identity from gait (reviewed by Blake & Shiffrar, 2007), evidence from a

study using point-light displays suggests that normal observers rely less on kinematic and form-from-motion cues to identify instrumental (goal-directed) and social actions than they do to identify non-instrumental (locomotory) actions (Dittrich, 1993). A secondary prediction of this study was therefore that, if individuals with ASD have difficulties perceiving coherent motion and thus bodily kinematics and changes in body form over time, then they would be more likely to show impaired identification of non-instrumental than instrumental actions.

Method

Participants

The ASD group comprised 13 adults (12 male) aged 18-58 years. Nine participants in the ASD group were recruited from the Psychology and Challenging Needs Service, Roselands Clinic, Surrey (UK); **the remaining 4** attended a specialist college run by the European Society for People with Autism, in Newcastle-upon-Tyne (UK). All ASD participants had been diagnosed by experienced clinicians (a psychiatrist or clinical psychologist employed by the National Health Service) as meeting DSM-IV criteria for either Asperger's Syndrome **(n=12)** or high-functioning autism **(n = 1)** (American Psychiatric Association, 1994). The typically developing (TD) group comprised 16 adults (14 male) aged 17-54 years, recruited from Durham University and a further education college in the Durham area.

The groups were group-wise matched on age, full-scale IQ, verbal IQ and performance IQ, as shown in Table 1. The ASD individuals' IQ was assessed using the Wechsler Abbreviated Scales of Intelligence (WASI: Wechsler, 1999) or the Wechsler Adult Intelligence Scale – Third Edition (WISC-III, Wechsler, 1997). Estimates of IQ for the TD individuals were derived using the revised version of the National Adult Reading Test (Blair & Spreen, 1989), which has good convergent validity with WAIS IQ scores (Crawford et al., 1989), and has been used for IQ-matching purposes in previous studies with ASD individuals (e.g., Beaumont & Newcombe, 2006; Lawson et al., 2004).

---------- Insert Table 1 about here. ----------

All participants gave signed, informed consent. Ethical approval was obtained from the National Health Service South London Research Ethics Committee and the Durham University Department of Psychology Ethics Advisory Committee.

Procedure, tasks and stimuli

All participants were tested individually, in a quiet room, completing 3 experimental tasks in the same fixed order within a single testing session. All 3 tasks were presented on the same computer monitor for all participants at a viewing distance of approximately 50cm. Standard instructions were provided verbally and on the monitor at the start of each task.

Forced-choice labelling of basic emotions. The stimuli were grey-scale digital movie clips depicting people expressing emotions with whole-body movement, as detailed in Atkinson, Tunstall and Dittrich (2007b) and Atkinson, Heberlein and Adolphs (2007a). (For example movies, see http://www.dur.ac.uk/a.p.atkinson/.) Participants viewed 10 intended portrayals of each of anger, disgust, fear, happiness and sadness in point-light displays, and 50 identical movement sequences in full-light displays. The full-light displays were drawn from the same set as that from which the stimuli used by Philip et al. (submitted) were drawn. While there was some overlap between the selected full-light sets for the two studies, they did not contain identical exemplars of each emotion; moreover, all stimuli in the present study had durations of 3 seconds, with the movements ending around the apex of the expression, whereas those used by Philip et al. varied in duration and showed the actor returning to a neutral stance.

The participants viewed all 50 point-light displays sequentially in a single block, followed by the 50 corresponding full-light displays. The stimuli were presented in a different random order for each block and for each participant. Each movie clip disappeared from the screen once it had run its length, upon which the participants were asked to press one of 5 keys to indicate which emotion label – angry, disgusted, fearful, happy, or sad – best described how the person in that movie clip was feeling. These response options appeared on the screen immediately upon termination of each movie clip, remaining until a response was made, after which the next clip appeared.

Forced-choice labelling of actions. The stimuli consisted in 3-second movie clips depicting actors portraying one of 8 different actions with whole-body movements: **4 instrumental actions (digging, kicking, knocking, pushing) and 4 non-instrumental actions (bending to touch toes, hopping, walking on the spot, and star-jumping or jumping jacks).** Participants viewed 4 different versions of each action in point-light displays followed by 32 identical movement sequences presented as full-light displays. (**The instrumental and non-instrumental actions were combined together into a single task with eight response options in an effort to reduce task performance below ceiling.** More exemplars of each action were not used because we had no reason to expect performance to differ between groups for any particular action.) The stimulus presentation and procedure were the same as for the previous task, except that the participants were asked to select one of 8 different action labels for each clip.

Motion coherence. The stimulus for this task comprised a series of briefly presented random dot kinematograms in the form of arrays of small white dots moving against a uniform black background. Each array consisted of 750 approximately 1mm diameter dots, presented within a rectangular area measuring 15cm high by 6.5cm wide. On any given trial, a proportion of these dots moved coherently either to the left or right, displacing a total of approximately 4mm over the course of 200ms, while each of the remaining dots moved at the same rate but in a direction (up, down, left, right or diagonally) that varied randomly from frame to frame. There were 12 presentations at each of 13 coherence levels, ranging from 2-100% (see Figure 1F). Each trial consisted in a larger white fixation dot in the centre of the screen for 1,000ms, immediately followed by the small dot array for 200ms. The time between the offset of the dot array and the onset of the fixation dot for the subsequent trial varied from 2600-7600ms, during which time the participant was required to make his or her response. These stimuli were presented as digital movie clips (25 frames per second). The 156 trials were randomly assigned to 3 movie clips (i.e., 52 in each), such that, for each clip, participants viewed a fixed random order of stimuli; the order of the 3 movie clips was counterbalanced across participants. A short break was allowed between each clip. The participants were told that some of the dots in each array would be moving together in one direction, either to the left or to the right. The participants were asked to indicate verbally, for each array, whether the direction of motion was to the left or right, and that they should guess if unsure. The experimenter recorded each answer on paper. Prior questioning confirmed that all participants were able to discriminate reliably left from right. If participants did not respond prior to the onset of the next stimulus the movie clip was stopped and, if necessary, that particular trial was replayed. This happened rarely and typically only within the first few trials of the first of the 3 blocks.

Results

Forced-choice emotion labelling

The proportion correct emotion classification responses (raw hit rates) made by the two groups for each stimulus condition are shown in Figure 1A-B. Inspection of the confusion matrices revealed that the patterns of assignment of emotion labels to intended bodily expressions were comparable to previous studies (Atkinson et al., 2004; Atkinson et al., 2007b; Dittrich et al., 1996) and were broadly similar across the two groups. Nonetheless, there were some differences between groups in the relative frequencies of response-label use.

To account for these response frequency differences, unbiased hit rates (Wagner, 1993), which express accuracy as a proportion of both response and stimulus frequencies, were used as the principle measure of interest (Figure 1C-D).

---------- Insert Figure 1 about here. ----------

An analysis of variance covariance (ANCOVA) was conducted to test for differences in emotion classification accuracy between groups, emotions, and stimulus display type, with participant age as a covariate. As age and FSIQ showed high correlations in both groups (ASD: *r* = .867, *p* < .001; TD: *r* = .752, *p* = .001; Spearman's rho), no additional adjustment for FSIQ was made to avoid colinearity. To reduce the impact of deviations from a normal distribution, the unbiased hit rates were first arcsine transformed. There was a highly significant main effect of group, *F*(1, 26) = 10.26, *p* < .005, with a large effect size, *r* = 0.53, reflecting less accurate emotion classification by the ASD individuals (*M* = 0.61, *SD* = 0.195) compared to the TD individuals (*M* = 0.846, *SD* = 0.196). This main effect of emotion was modified by a marginally significant Group X Emotion interaction, *F*(4, 104) = 2.4, *p* = .055. Simple main effects analyses, with age as a covariate, confirmed that the ASD group was significantly less accurate than the TD group in classifying expressions of anger and happiness (both *p*s < .01), but not expressions of fear or sadness (both *p*s > .1). Due to violation of the homogeneity of slopes assumption, an ANCOVA was not performed on accuracy scores for expressions of disgust. While an ANOVA confirmed that the ASD group was significantly less accurate than the TD group in classifying expressions of disgust, *F*(1, 27) = 11.03, *p* < .005, *r* = 0.54, this result should be interpreted with caution, as age was significantly correlated with disgust classification accuracy in the ASD group (*r* = -.584, *p* < .05) but not in the TD group (*r* = .035, *p* > .85). The 3-way ANCOVA also revealed a marginally significant relationship between stimulus display

type and participant age, *F*(1, 26) = 3.88, *p* = .06, reflecting a significant negative correlation between age and emotion classification accuracy for the point-light displays (*r* = -.534, *p* < .005) but not for the full-light displays (*r* = -.295, *p* > .1). There were no other significant main effects or interactions (all *p*s > .08).

Motion coherence

Figure 1E shows the accuracy of the two groups on the motion coherence task as a function of the percentage of dots that were moving coherently to the left or right. To test for differences between groups, an ANOVA was conducted with group as the between-subjects variable and coherence level as a repeated-measures variable. **(Variations in age and IQ were not significantly correlated with performance at any of the coherence levels, all *p*s > .05; thus it was deemed unnecessary to statistically control for these variables.) Overall motion coherence accuracy was significantly greater in the TD group than in the ASD group, *F*(1, 29) = 6.33, *p* < .05, *r* = .47. There was also a significant main effect of coherence level, *F*(6.3, 170.9) = 15.67, *p* < .001 (Greenhouse-Geisser corrected), but no significant interaction between group and coherence level (*p* > .4).**

To explore further the group difference in the perception of coherent motion and to enable examination of the relationship between performance on the motion coherence and bodily emotion recognition tasks, motion coherence thresholds were calculated for each participant. First, psychometric functions were fitted to each participant's data using the psignifit toolbox version 2.5.6 for Matlab (see http://bootstrap-software.org/psignifit/), which implements the maximum-likelihood method described by Wichmann and Hill (2001). The Gumbel function was used, with the 13 coherence levels plotted on a logarithmic scale. Psychometric functions could not be adequately fitted to the data of 4 participants from the TD group (3 of whom were at ceiling). Log-scaled motion coherence thresholds for 75% correct performance (a standard cutoff) were extrapolated from the psychometric functions for each remaining participant. The log-scaled motion coherence thresholds were then compared across groups using a one-tailed Kolmogorov-Smirnov *Z* test. The ASD group had larger motion coherence thresholds (*Mdn* = 19.2%, *M* = 23.5%, *SD* = 22.0) than the TD group (*Mdn* = 10.4%, *M* = 12.1%, *SD* = 11.8), a difference that was borderline significant, *Z* = 1.12, *p* = .054, with a small-medium effect size, *r* = .23.

Relationship between motion coherence thresholds and emotion classification accuracy

Linear multiple regression analyses were conducted to test the extent to which the independent variables of group, log-scaled motion coherence thresholds, PIQ, VIQ and age predicted unbiased emotion classification hit rates for the point-light and, separately, the full-light body movement stimuli. Initial, exploratory backward stepwise regression analyses revealed that the significant predictors of overall emotion classification accuracy (collapsed across emotion category) for the point-light displays were group, motion coherence threshold, **and VIQ** (all *p*s < .05, overall R^2 = .579). **A forced-entry hierarchical regression analysis was then conducted, excluding variables that were statistically redundant. To control for the influence of VIQ, this variable was entered in a first step. Motion coherence thresholds and participant group were entered in the second and third steps, respectively. Motion coherence thresholds significantly accounted for 31.8% of the variance in emotion classification scores for the point-light displays (β = -.57, *t* = -3.63, *p* = .001) over and above that accounted for by VIQ, with participant group significantly accounting for an additional 11% of the variance (β = -.34, *t* = -2.35, *p* < .05). Motion coherence thresholds did not predict overall emotion classification accuracy for the full-light displays, however (*p* > .1); the only significant predictor was group, accounting for 30.1% of the variance in emotion classification accuracy (β = -.55, *t* = -3.15, *p* < .01).** Motion coherence thresholds themselves were unrelated to age or any of the IQ measures (all *p*s > .5, Spearman's rho, 2-tailed). **Application of the Chow test (Chow, 1960) confirmed**

that the relationship between motion coherence thresholds and emotion classification accuracy was significantly greater for the ASD group than for the TD group for both the point-light displays, *F*(1, 22) = 12.41, *p* < .005, and the full-light displays, *F*(1, 22) = 20.01, *p* < .001.

Further linear regression analyses were conducted on the unbiased emotion-classification hit rates, separately for each group and stimulus display type (collapsed across emotion category). For the ASD group, log-scaled motion coherence thresholds significantly accounted for 74% of the variance in emotion classification scores for the point-light displays ($\beta = -.87$, $t = -7.1$, $p = .001$) and 55.8% of the variance for the full-light displays ($\beta = -.76$, $t = -3.85$, $p < .005$), after controlling for the effects of VIQ. On its own, VIQ did not significantly account for variance in emotion classification scores for either the point-light or full-light displays (both *p*s> .25); nonetheless, with motion coherence thresholds included in the model, VIQ did significantly account for remaining variance in emotion classification scores for the point-light displays, R^2 change = .218, $\beta = -.47$, $t = -3.86$, $p < .005$, but not for the full-light displays ($p > .08$). For the TD group, motion coherence thresholds and VIQ did not significantly predict overall emotion classification accuracy for either the point-light or full-light displays (both *p*s > .15).

Follow-up regression analyses revealed that, for the ASD group, motion coherence thresholds significantly predicted emotion classification accuracy for all 5 emotions in the point-light displays (R^2 range from .35 for sadness to .64 for disgust, **β range -.59 for sadness to -.8 for disgust**, all *p*s < .05), but only for disgust, fear and sadness in the full-light displays (R^2 range from .31 for disgust to .64 for fear, β range -.56 for disgust to -.8 for fear, all *p*s < .05). **For the TD group, motion coherence thresholds and VIQ did not**

significantly predict emotion classification accuracy for any specific emotion in either the point-light or full-light displays (all *p*s > .15).

Forced-choice labelling of non-emotional actions

Figure 1F shows the accuracy of the two groups on the action-labelling task as a function of stimulus display type and action type. Given the large departures from normality in the distributions of the action classification scores, differences between groups with respect to the unbiased hit rates were assessed using one-tailed Kolmogorov-Smirnov *Z* tests. **The ASD group was significantly less accurate than the TD group overall (i.e., collapsed across action and stimulus display types), $Z = 1.09$, $p < .05$, $r = .202$. None of the comparisons between groups for the 4 individual stimulus conditions depicted in Figure 1F survived correction for multiple comparisons using the Bonferroni method (all *p*s > .0125). Nonetheless, the means of the individual ASD participant z-scores for the 4 stimulus conditions revealed a clear trend for greater impairment for non-instrumental than instrumental actions: full-light non-instrumental ($z = -2.17$) > point-light non-instrumental ($z = -1.59$) > point-light instrumental ($z = -0.71$) > full-light instrumental ($z = -0.5$).**

Finally, linear regression analyses were conducted to test whether log-scaled motion coherence thresholds predicted accuracy in classifying non-emotional actions by the ASD group. (A similar regression analysis for the TD group was judged to be unwarranted, given the insufficient variation in this group's action classification scores.) No significant relationships were evident, either for the instrumental or non-instrumental actions in either the point-light or full-light displays (all *p*s > .4); PIQ, VIQ and age did not predict action classification accuracy either (all *p*s > .1). Regressing the differences in ASD individuals' unbiased hit rates between the emotion and action classification tasks (collapsed across emotion and action type) on log-scaled motion

coherence thresholds revealed a significantly greater relationship between motion coherence thresholds and classification accuracy for the emotional movements than for the non-emotional actions in the point-light displays ($R^2 = .47$, $\beta = -.69$, $t = -3.15$, $p < .01$) and in the full-light displays ($R^2 = .42$, $\beta = -.65$, $t = -2.83$, $p < .05$).

Discussion

In this study, a group of adults diagnosed on the autism spectrum and a comparison group of typically developing adults, matched for chronological age and IQ, were tested on tasks that measured abilities to classify basic emotions from point-light and full-light displays of body movements and to detect simple coherent motion. **The ASD group was reliably less accurate in classifying bodily expressions of anger, happiness and disgust, regardless of stimulus display type, and marginally but not significantly less accurate in classifying bodily expressions of fear and sadness. These findings broadly replicate and extend** the results of previous studies of bodily emotion recognition in ASD (Hubert et al., 2007; Moore et al., 1997; Philip et al., submitted). The ASD group was also impaired relative to the TD group in discriminating translational coherent motion from random-dot kinematograms. Furthermore, as predicted, ASD individuals with higher motion coherence thresholds were less accurate in classifying emotions from body movements, especially in the point-light displays. No such relationship between log-scaled motion coherence thresholds and emotion classification accuracy was evident in the TD group. **The reason for this latter finding is uncertain and deserves further investigation; one possible reason is that TD individuals with higher motion coherence thresholds employed a compensatory strategy, perhaps relying more on different perceptual mechanisms, which the ASD individuals were less able to employ.**

These results are consistent with the hypothesis that impaired recognition of bodily expressed emotions in ASD is at least partly attributable to a deficit in visual motion processing, as opposed to being an entirely higher-level deficit in attributing emotions or mental states more generally. It was reasoned that impaired discrimination of simple coherent motion would be associated with impaired ability to classify emotions from body movements because detection of coherent motion requires integration of more global than local motion signals, and successful discrimination and recognition of bodily expressed emotions relies to some extent on the processing of bodily kinematics, which in turn also requires integration of relatively global motion signals.

The ASD group was also less accurate than the TD group in classifying whole-body non-instrumental actions from point-light and full-light displays. This finding is consistent with there being a difficulty associated with ASD in processing bodily kinematics, given the more prominent role such cues play in the identification of non-instrumental compared to instrumental actions (Dittrich, 1993). However, action classification accuracy was unrelated to motion coherence thresholds. There are at least two possible reasons for this. One reason is as follows. There is growing evidence that successful discrimination of bodily movements or actions depends on the relative balance of different visual cues – kinematics, featural and configural motion and form cues – and that the relative contributions of these cues varies depending on the type of action and on task requirements (e.g., Atkinson et al., 2007b; Dittrich, 1993; Loucks & Baldwin, 2009). Moreover, there is evidence that distinct neural systems process these different cues and thus subserve the perception of different types of movement (e.g., Gallagher & Frith, 2004; Lestou et al., 2008). Thus the reason that motion coherence thresholds were related to accuracy in judging emotions but not instrumental or non-instrumental actions might be that discrimination of emotionally expressive movements relies more on cues requiring relatively global motion and form processing, such as kinematic and configural cues, than does the discrimination of non-instrumental and

especially instrumental actions, which relies more on the processing of relatively local motion and form cues. Alternatively, the reason might simply be that there was not enough variation in action classification scores, as a consequence of the task being too easy. These two possible reasons are not mutually exclusive and both deserve further investigation.

What neural mechanisms might underlie this relationship between the abilities to perceive global, coherent motion and to recognize emotions from body movements? One recent model emphasizes that the perception of human body movements involves the spatiotemporal integration of local motion and local form signals (Giese & Poggio, 2003). Another recent model proposes that the perception of body movement is achieved via the temporal integration of global static body form (Lange & Lappe, 2006). Both models are consistent with impaired bodily emotion recognition being associated with impaired perception of coherent or global motion, and central to both is the superior temporal sulcus (STS). The STS, especially its posterior aspect, has an important role in the visual analysis of body and facial movement (Puce & Perrett, 2003) and may be involved with the interpretation of any social signal with a temporal component (Calder & Young, 2005). The STS also has associated roles in the detection of agency and the interpretation of other people's actions (Frith & Frith, 2003; Pelphrey & Morris, 2006).

ASD is associated with compromised functioning of a neural network critically involving regions in and around the STS (e.g., Dakin & Frith, 2005; Frith, 2001; Zilbovicius et al., 2006). For example, individuals with ASD show reduced STS activation in response to a variety of socially relevant motion stimuli, including body movements (Freitag et al., 2008; Herrington et al., 2007) and emotional face movements (Pelphrey et al., 2007). Functional abnormalities of the fusiform cortex have also been widely reported in ASD, principally in response to faces (e.g., Hadjikhani et al., 2007; Pierce et al., 2001; Schultz et al., 2003); there is also evidence of structural abnormalities in this region (van Kooten et al., 2008) as well as of abnormal functional connectivity of the fusiform with frontal regions and the amygdala (Kleinhans et al., 2008; Koshino et al., 2008). The fusiform gyrus contains one of two regions selective for human body form (Peelen & Downing, 2005), the other being the extrastriate body area (Downing et al., 2001), and in TD adults the activity of both these regions is selectively enhanced by emotional compared to neutral full-light body movements, as is the activity of the amygdala (Peelen et al., 2007). It has recently been reported that individuals with ASD, unlike TD individuals, did not show increased activation to fearful compared to neutral static body postures in the fusiform and amygdala, amongst other brain regions (Hadjikhani et al., 2009), **or to fearful compared to neutral bodies irrespective of whether they were static or dynamic, in the amygdala, inferior frontal gyrus and premotor cortex (Grèzes et al., 2009)**. **Moreover, relative to a TD group, ASD individuals showed significantly reduced activation to dynamic v. static bodies, irrespective of whether they were fearful or neutral gestures, in several brain regions, including right STS and fusiform, but showed a similar level of activation in STS for fearful v. neutral gestures irrespective of whether they were static or dynamic (Grèzes et al., 2009). Atypical patterns of functional connectivity were also found in the ASD group, including a lack of change in connectivity strength when viewing fearful compared to neutral bodies between amygdala and each of STS, premotor cortex and inferior frontal gyrus (Grèzes et al., 2009). Future research should examine the relationship between impairments in global motion perception and the recognition of a range of emotions in ASD in the context of compromised functioning of and connectivity between these key brain regions.**

Footnotes

1. In point-light displays the only visible elements are small lights or patches attached to the major joints and head of the actor, which minimizes or eliminates static form information but preserves motion (including form-from-motion) information (Johansson, 1973). In full-light displays, in contrast, the whole body and head are visible but the face is not (Atkinson et al., 2004).

References

Ashwin, C., Chapman, E., Colle, L., & Baron-Cohen, S. (2006). Impaired recognition of negative basic emotions in autism: A test of the amygdala theory. *Social Neuroscience, 1*(3-4), 349-363.

Atkinson, A. P., Dittrich, W. H., Gemmell, A. J., & Young, A. W. (2004). Emotion perception from dynamic and static body expressions in point-light and full-light displays. *Perception, 33*(5), 717-746.

Atkinson, A. P., Heberlein, A. S., & Adolphs, R. (2007a). Spared ability to recognise fear from static and moving whole-body cues following bilateral amygdala damage. *Neuropsychologia, 45*(12), 2772-2782.

Atkinson, A. P., Tunstall, M. L., & Dittrich, W. H. (2007b). Evidence for distinct contributions of form and motion information to the recognition of emotions from body gestures. *Cognition, 104*(1), 59-72.

Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and theory of mind*. Cambridge, MA: MIT Press/ Bradford Books.

Beaumont, R., & Newcombe, P. (2006). Theory of mind and central coherence in adults with high-functioning autism or Asperger syndrome. *Autism, 10*(4), 365-382.

Blair, J. R., & Spreen, O. (1989). Predicting premorbid IQ: A revision of the National Adult Reading Test. *The Clinical Neuropsychologist, 3*(2), 129-136.

Blake, R., & Shiffrar, M. (2007). Perception of human motion. *Annual Review of Psychology, 58*, 47-73.

Blake, R., Turner, L. M., Smoski, M. J., Pozdol, S. L., & Stone, W. L. (2003). Visual recognition of biological motion is impaired in children with autism. *Psychological Science, 14*(2), 151-157.

Calder, A. J., & Young, A. W. (2005). Understanding the recognition of facial identity and facial expression. *Nature Reviews Neuroscience, 6*(8), 641-651.

Chow, G. C. (1960). Tests of equality between sets of coefficients in 2 linear regressions. *Econometrica, 28*(3), 591-605.

Crawford, J. R., Parker, D. M., Stewart, L. E., Besson, J. A. O., & Delacey, G. (1989). Prediction of WAIS IQ with the National Adult Reading Test: Cross-validation and extension. *British Journal of Clinical Psychology, 28*, 267-273.

Dakin, S., & Frith, U. (2005). Vagaries of visual perception in autism. *Neuron, 48*(3), 497-507.

Del Viva, M. M., Igliozzi, R., Tancredi, R., & Brizzolara, D. (2006). Spatial and motion integration in children with autism. *Vision Research, 46*(8-9), 1242-1252.

Diagnostic and statistical manual of the American Psychiatric Association (DSM-IV). (1994). (4th ed.). Washington D.C.: American Psychiatric Association.

Dittrich, W. H. (1993). Action categories and the perception of biological motion. *Perception, 22*(1), 15-22.

Dittrich, W. H., Troscianko, T., Lea, S., & Morgan, D. (1996). Perception of emotion from dynamic point-light displays represented in dance. *Perception, 25*(6), 727-738.

Downing, P. E., Jiang, Y., Shuman, M., & Kanwisher, N. (2001). A cortical area selective for visual processing of the human body. *Science, 293*(5539), 2470-2473.

Freitag, C. M., Konrad, C., H‰berlen, M., Kleser, C., von Gontard, A., Reith, W., et al. (2008). Perception of biological motion in autism spectrum disorders. *Neuropsychologia, 46*(5), 1480-1494.

Frith, U. (2001). Mind blindness and the brain in autism. *Neuron, 32*(6), 969-979.

Frith, U., & Frith, C. D. (2003). Development and neurophysiology of mentalizing. *Philosophical Transactions of the Royal Society of London Series B: Biological Sciences, 358*(1431), 459-473.

Gallagher, H. L., & Frith, C. D. (2004). Dissociable neural pathways for the perception and recognition of expressive and instrumental gestures. *Neuropsychologia, 42*(13), 1725-1736.

Giese, M. A., & Poggio, T. (2003). Neural mechanisms for the recognition of biological movements. *Nature Reviews Neuroscience, 4*(3), 179-192.

Grèzes, J., Wicker, B., Berthoz, S., & de Gelder, B. (2009). A failure to grasp the affective meaning of actions in autism spectrum disorder subjects. *Neuropsychologia, 47*(8-9), 1816-1825.

Hadjikhani, N., Joseph, R. M., Manoach, D. S., Naik, P., Snyder, J., Dominick, K., et al. (2009). Body expressions of emotion do not trigger fear contagion in autism spectrum disorder. *Social Cognitive and Affective Neuroscience, 4*(1), 70-78.

Hadjikhani, N., Joseph, R. M., Snyder, J., & Tager-Flusberg, H. (2007). Abnormal activation of the social brain during face perception in autism. *Human Brain Mapping, 28*(5), 441-449.

Herrington, J. D., Baron-Cohen, S., Wheelwright, S. J., Singh, K. D., Bullmore, E. T., Brammer, M., et al. (2007). The role of MT+/V5 during biological motion perception in Asperger Syndrome: An fMRI study. *Research in Autism Spectrum Disorders, 1*(1), 14-27.

Hobson, R. P., Ouston, J., & Lee, A. (1988). Emotion recognition in autism: coordinating faces and voices. *Psychological Medicine, 18*(4), 911-923.

Hubert, B., Wicker, B., Moore, D. G., Monfardini, E., Duverger, H., Da Fonseca, D., et al. (2007). Recognition of emotional and non-emotional biological motion in individuals with autistic spectrum disorders. *Journal of Autism and Developmental Disorders, 37*(7), 1386-1392.

Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. *Perception and Psychophysics, 14*(2), 201-211.

Kleinhans, N. M., Richards, T., Sterling, L., Stegbauer, K. C., Mahurin, R., Johnson, L. C., et al. (2008). Abnormal functional connectivity in autism spectrum disorders during face processing. *Brain, 131*(4), 1000-1012.

Koshino, H., Kana, R. K., Keller, T. A., Cherkassky, V. L., Minshew, N. J., & Just, M. A. (2008). fMRI investigation of working memory for faces in autism: Visual coding and underconnectivity with frontal areas. *Cerebral Cortex, 18*(2), 289-300.

Lange, J., & Lappe, M. (2006). A model of biological motion perception from configural form cues. *Journal of Neuroscience, 26*(11), 2894-2906.

Lawson, J., Baron-Cohen, S., & Wheelwright, S. (2004). Empathising and systemising in adults with and without Asperger Syndrome. *Journal of Autism and Developmental Disorders, 34*(3), 301-310.

Lestou, V., Pollick, F. E., & Kourtzi, Z. (2008). Neural substrates for action understanding at different description levels in the human brain. *Journal of Cognitive Neuroscience, 20*(2), 324-341.

Loucks, J., & Baldwin, D. (2009). Sources of information for discriminating dynamic human actions. *Cognition, 111*(1), 84-97.

Milne, E., Swettenham, J., & Campbell, R. (2005). Motion perception and autistic spectrum disorder: A review. *Cahiers de Psychologie Cognitive/ Current Psychology of Cognition, 23*(1), 3-36.

Milne, E., Swettenham, J., Hansen, P., Campbell, R., Jeffries, H., & Plaisted, K. (2002). High motion coherence thresholds in children with autism. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 43*(2), 255-263.

Milne, E., White, S., Campbell, R., Swettenham, J., Hansen, P., & Ramus, F. (2006). Motion and form coherence detection in autistic spectrum disorder: Relationship to motor control and 2 : 4 digit ratio. *Journal of Autism and Developmental Disorders, 36*(2), 225-237.

Moore, D. G., Hobson, R. P., & Lee, A. (1997). Components of person perception: An investigation with autistic, non-autistic retarded and typically developing children and adolescents. *British Journal of Developmental Psychology, 15*(4), 401-423.

Peelen, M. V., Atkinson, A. P., Andersson, F., & Vuilleumier, P. (2007). Emotional modulation of body-selective visual areas. *Social Cognitive and Affective Neuroscience, 2*(4), 274-283.

Peelen, M. V., & Downing, P. E. (2005). Selectivity for the human body in the fusiform gyrus. *Journal of Neurophysiology, 93*(1), 603-608.

Pellicano, E., Gibson, L., Maybery, M., Durkin, K., & Badcock, D. R. (2005). Abnormal global processing along the dorsal visual pathway in autism: a possible mechanism for weak visuospatial coherence? *Neuropsychologia, 43*(7), 1044-1053.

Pelphrey, K. A., & Morris, J. P. (2006). Brain mechanisms for interpreting the actions of others from biological-motion cues. *Current Directions in Psychological Science, 15*(3), 136-140.

Pelphrey, K. A., Morris, J. P., McCarthy, G., & LaBar, K. S. (2007). Perception of dynamic changes in facial affect and identity in autism. *Social Cognitive and Affective Neuroscience, 2*(2), 140-149.

Pelphrey, K. A., Sasson, N. J., Reznick, J. S., Paul, G., Goldman, B. D., & Piven, J. (2002). Visual scanning of faces in autism. *Journal of Autism and Developmental Disorders, 32*(4), 249-261.

Perner, J., Frith, U., Leslie, A. M., & Leekam, S. R. (1989). Exploration of the autistic child's theory of mind: knowledge, belief, and communication. *Child Development, 60*(3), 688-700.

Philip, R. C. M., Hall, J., Whalley, H., Stanfield, A. C., Sprengelmeyer, R., Young, A. W., et al. (submitted). Cross-modal deficits in emotion processing in autistic spectrum disorder.

Pierce, K., Muller, R. A., Ambrose, J., Allen, G., & Courchesne, E. (2001). Face processing occurs outside the fusiform 'face area' in autism: evidence from functional MRI. *Brain, 124*(Pt 10), 2059-2073.

Pollick, F. E., Paterson, H. M., Bruderlin, A., & Sanford, A. J. (2001). Perceiving affect from arm movement. *Cognition, 82*(2), B51-61.

Puce, A., & Perrett, D. (2003). Electrophysiology and brain imaging of biological motion. *Philosophical Transactions of the Royal Society of London, Series B: Biological Sciences, 358*(1431), 435-445.

Roether, C. L., Omlor, L., & Giese, M. A. (2008). Lateral asymmetry of bodily emotion expression. *Current Biology, 18*(8), R329-R330.

Schultz, R. T., Grelotti, D. J., Klin, A., Kleinman, J., Van der Gaag, C., Marois, R., et al. (2003). The role of the fusiform face area in social cognition: implications for the pathobiology of autism. *Philosophical Transactions of the Royal Society, London, B: Biological Sciences, 358*(1430), 415-427.

Spencer, J., O'Brien, J., Riggs, K., Braddick, O., Atkinson, A., & Wattam-Bell, J. (2000). Motion processing in autism: evidence for a dorsal stream deficiency. *Neuroreport, 11*(12), 2765-2767.

Tsermentseli, S., O'Brien, J. M., & Spencer, J. V. (2008). Comparison of form and motion coherence processing in autistic spectrum disorders and dyslexia. *Journal of Autism and Developmental Disorders, 38*(7), 1201-1210.

van Kooten, I. A. J., Palmen, S. J. M. C., von Cappeln, P., Steinbusch, H. W. M., Korr, H., Heinsen, H., et al. (2008). Neurons in the fusiform gyrus are fewer and smaller in autism. *Brain, 131*(4), 987-999.

Wagner, H. L. (1993). On measuring performance in category judgment studies of nonverbal behavior. *Journal of Nonverbal Behavior, 17*(1), 3-28.

Wechsler, D. (1997). *Wechsler Adult Intelligence Scale - Third Edition*. San Antonio, TX: The Psychological Corporation.

Wechsler, D. (1999). *Wechsler Abbreviated Scale of Intelligence.* San Antonio, Tx: Psychological Coorporation.

Wichmann, F. A., & Hill, N. J. (2001). The psychometric function: I. Fitting, sampling, and goodness of fit. *Perception and Psychophysics, 63*(8), 1293-1314.

Zilbovicius, M., Meresse, I., Chabane, N., Brunelle, F., Samson, Y., & Boddaert, N. (2006). Autism, the superior temporal sulcus and social perception. *Trends in Neurosciences, 29*(7), 359-366.

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Table 1. Demographic data and group matching for ASD and TD groups

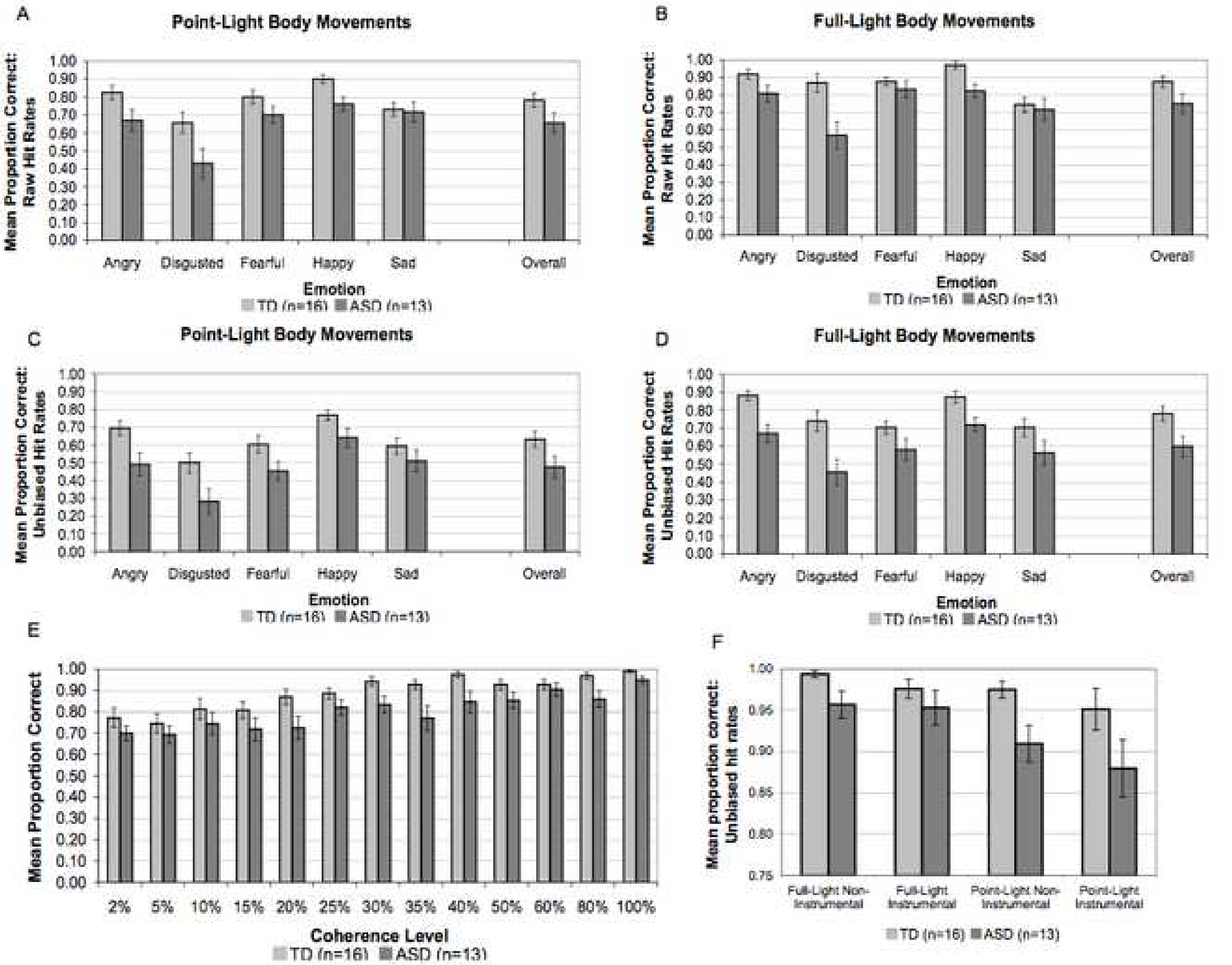
	ASD (n = 13)			TD (n = 16)				
	Mean	Median	SD	Mean	Median	SD	U^a	p value^b
Age	30.9	26.0	13.8	26.7	20.0	12.8	76.5	.23
VIQ	106.9	110.0	11.6	105.7	109.0	10.0	91.5	.6
PIQ	105.2	110.0	13.5	108.4	108.5	4.8	100.0	.87
FSIQ	106.2	110.0	12.2	106.6	106.5	8.5	99.0	.84

Note. Non-parametric tests were used because, for each variable, one or other or both of the normality and homogeneity of variance assumptions was broken (as indicated by, respectively, the Shapiro-Wilk and Levene tests; all *p*s < .05). Medians are reported as well as means for all variables, as medians are generally regarded as more meaningful for non-parametric tests. $^a U$ = Mann-Whitney U. ^{b}Two-tailed significance. VIQ: verbal intelligence quotient; PIQ: performance intelligence quotient; FSIQ: full-scale intelligence quotient.

Figure Caption

Figure 1. A-D: Forced-choice emotion classification accuracy, as a function of participant group, emotion category, and stimulus display type, for the raw hit rates (A and B) and unbiased hit rates (C and D). ***E:* Accuracy on the motion coherence task (left/right judgement), as a function of coherence level and participant group. *F*: Forced-choice action classification accuracy, as a function of participant group, action and stimulus display types. ASD: autism spectrum disorder group; TD: typically developing control group. ASD: autism spectrum disorder group; TD: typically developing control group.**

Figure


A
Point-Light Body Movements
Mean Proportion Correct: Raw Hit Rates
1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.00
Angry Disgusted Fearful Happy Sad Overall
Emotion
TD (n=16) ASD (n=13)
B
Full-Light Body Movements
Mean Proportion Correct: Raw Hit Rates
1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.00
Angry Disgusted Fearful Happy Sad Overall
Emotion
TD (n=16) ASD (n=13)
C
Point-Light Body Movements
Mean Proportion Correct: Unbiased Hit Rates
1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.00
Angry Disgusted Fearful Happy Sad Overall
Emotion
TD (n=16) ASD (n=13)
D
Full-Light Body Movements
Mean Proportion Correct Unbiased Hit Rates
1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.00
Angry Disgusted Fearful Happy Sad Overall
Emotion
TD (n=16) ASD (n=13)
E
Mean Proportion Correct
1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.00
2% 5% 10% 15% 20% 25% 30% 35% 40% 50% 60% 80% 100%
Coherence Level
TD (n=16) ASD (n=13)
F
Mean proportion correct: Unbiased hit rates
1.00 0.95 0.90 0.85 0.80 0.75
Full-Light Non-Instrumental
Full-Light Instrumental
Point-Light Non-Instrumental
Point-Light Instrumental
TD (n=16) ASD (n=13)