Running head: Dot lifetime and coherent motion processing in autism

Coherent motion processing in autism: Is dot lifetime an important parameter?

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Abstract

Contrasting reports of *reduced* and *intact* sensitivity to coherent motion in autistic individuals may be attributable to stimulus parameters. Here, we investigated whether dot lifetime contributes to elevated thresholds in children with autism. We presented a standard motion coherence task to 31 children with autism and 31 typical children, with both limited and unlimited lifetime conditions. Overall, children had higher thresholds in the limited lifetime condition than in the unlimited lifetime condition. Yet children with autism were affected by this manipulation to the same extent as typical children and were equally sensitive to coherent motion. Our results suggest that dot lifetime is not a critical stimulus parameter and speak against pervasive difficulties in coherent motion perception in children with autism.

Coherent motion processing in autism: Is dot lifetime an important parameter?

Global motion processing is crucial for interpreting dynamic sensory input, enabling observers to perceive the overall direction of a shoal of fish or a crowd of people, for example. Global motion perception is commonly assessed using the motion coherence paradigm, which requires observers to perceive a proportion of coherently moving dots amongst randomly moving noise dots (Newsome & Paré, 1988). Research has suggested that individuals with autism are less sensitive to global motion information than typically developing (TD) individuals in this task (e.g., Davis et al., 2006; Milne et al., 2002; Pellicano et al., 2005; Spencer et al., 2000). However, other authors have found no differences in coherent motion sensitivity between individuals with autism and typical individuals (e.g., de Jonge et al., 2007; Del Viva et al., 2006; Jones et al., 2011; Koldewyn et al., 2013). While these discrepant findings could in part reflect cohort differences, recent research has suggested that task and stimulus parameters are critical. For example, Robertson et al. (2012) reported elevated motion coherence thresholds in autistic individuals only at short (200ms) but not longer (400ms, 1500ms) stimulus durations. Ronconi et al. (2012) reported elevated thresholds only for stimuli viewed centrally and not peripherally, and Manning et al. (2013) reported elevated thresholds only for slow (1.5°/s) and not fast (6°/s) stimuli.

Another candidate parameter that may contribute to discrepant findings is the length of time that each stimulus dot persists on the screen, namely dot lifetime. Short dot lifetimes are often used to prevent the ability to track individual dots (e.g., Jackson et al., 2013; Milne et al., 2002) and lead to elevated motion coherence thresholds in typical adults (Braddick et al., 1998; Festa & Welch, 1997; Hiris & Blake, 1995; Jackson et al., 2013). Yet there are other reasons why short lifetimes might lead to elevated motion coherence thresholds, besides precluding tracking strategies. For example, short lifetimes a) introduce false correspondences between dots on successive frames (i.e., correspondence noise; Barlow & Tripathy, 1997), b) reduce the strength of activations within short-range filters (Pilly & Seitz, 2009; Watamaniuk et al., 2003), c) increase the need for temporal integration (Festa & Welch, 1997), and d) interfere with temporal smoothness (Lee & Lu, 2010; Watamaniuk et al., 2003).

Dot lifetime might therefore have a disproportionately disruptive effect on the motion coherence thresholds of individuals with autism. Some authors have proposed that individuals with autism have difficulties dealing with correspondence noise (Simmons et al., 2009) and atypical temporal integration (Robertson et al., 2012), both of which would lead to particularly elevated thresholds when short dot lifetimes are used. Preliminary support for this hypothesis is provided by Jackson et al. (2013), who compared the motion coherence thresholds of adults in the general population with varying levels of autistic traits, measured by the autism-spectrum quotient (AQ; Baron-Cohen et al., 2001). The performance of those reporting high levels of autistic traits (i.e., high AQ-scorers) was more disrupted by the introduction of limited lifetime than that of low AQ-scorers, and high AQ-scorers showed *enhanced* sensitivity to coherent motion in the unlimited lifetime condition compared to low AQ-scorers. Elevated motion coherence thresholds have previously been reported with a range of different dot lifetimes (e.g., Spencer & O'Brien, 2006: 50ms; Milne et al., 2002: 224ms). However, the influence of dot lifetime can only be fully assessed in a within-participants design where all other stimulus parameters are controlled.

This study directly tested the possibility that dot lifetime has a disproportionate effect on the motion coherence thresholds of children with autism compared to those of TD children. A motion coherence task was presented to children with autism aged 7 to 13 years and TD children matched in age and non-verbal ability with two stimulus conditions, limited and unlimited lifetime. The motion coherence task was based on that used by Manning et al.

(2013) and stimuli moved at a slow speed (1.5°/s). Manning et al. previously reported that children with autism had elevated thresholds in this task for slow-moving (1.5°/s) limited lifetime stimuli. We therefore predicted that children with autism would show elevated motion coherence thresholds in the limited lifetime condition compared to TD children. Importantly, however, we also hypothesised that the dot lifetime manipulation would have a particularly pronounced effect on the motion coherence thresholds of children with autism.

Methods

Participants

Thirty-one children with autism (*M* = 10 years; 11 months, range 7; 3 – 13; 6, 2 females) and thirty-one TD children (*M* = 10 years; 9 months, range 7; 9 - 13; 10, 10 females) were recruited through schools and community contacts within the Greater London area[1]. All children were cognitively able (verbal and performance IQ > 70) as assessed by the Wechsler Abbreviated Scales of Intelligence (WASI or WASI-II; Wechsler, 1999, 2011). Children with autism had previously received a diagnosis of an autism spectrum condition according to ICD-10 criteria (WHO, 1993). Parents of typically developing children and children with autism completed the Social Communication Questionnaire (SCQ; Rutter et al., 2003) and children with autism were administered the Autism Diagnostic Observation Schedule (ADOS-G or ADOS-2; Lord et al., 1999; 2012) using the revised algorithm (Gotham et al., 2007; 2008). All children with autism scored above threshold for an autism spectrum condition on at least one of these measures (Manning et al., 2013)[2] and all TD children scored below the cut-off for autism on the SCQ (< 15; Rutter et al., 2003). All children had normal or corrected-to-normal acuity, defined as a binocular acuity of 6/9 or better for children aged 7 to 8 years and 6/6 or better for older children. The groups did not differ in terms of chronological age, $t(60) = .39$, $p = .70$ or non-verbal ability, $t(60) = 1.26$, $p = .21$. Participant demographics are provided in Table 1.

Insert Table 1 about here

Apparatus and stimuli

Stimuli were presented on a Dell Precision M4600 laptop (1366 x 768 pixels; 60Hz) using MATLAB and elements of the Psychophysics Toolbox (Brainard, 1997; Kleiner et al., 2007; Pelli, 1997). Red and blue square apertures (11° x 11°) were presented to the left and right of a fly-shaped fixation point (1.54° x 3.12°), respectively, on a black screen (see Figure 1). The colour of the fixation point marked trial events: green to prompt fixation, red during stimulus presentation, and yellow while participants responded. Stimuli comprised 100 white dots (diameter = 0.34°) drifting at a speed of 1.5°/s within either the red or blue aperture for 1000ms. In the limited lifetime condition, each dot had a lifetime of 5 monitor refreshes (~83ms) before decaying and being replaced by a new dot in a random location. In the unlimited lifetime condition, each dot remained on the screen for the full duration of the stimulus, unless it drifted outside of the aperture, in which case it was randomly replaced within the aperture.

Insert Figure 1 about here

Procedure

Participants completed a motion coherence task in each of two conditions: limited lifetime and unlimited lifetime. The motion coherence task was the same as that described by Manning et al. (2013). A trial consisted of a pair of stimuli presented sequentially separated by a 500ms interstimulus interval in which the apertures and fixation point remained on the screen. A stimulus in the left (red) aperture was followed by a stimulus in the right (blue) aperture, and vice versa (Figure 1). The target stimulus contained a percentage of coherently moving dots while the non-target stimulus consisted entirely of randomly moving dots. The order of presentation of stimuli (target, non-target) and the direction of coherent motion (left, right) was randomised across trials.

Children were told that there were two species of firefly in ‘Insectland’: one with flashing lights (corresponding to the limited lifetime condition) and one with non-flashing lights (corresponding to the unlimited lifetime condition). Children were asked to work out which set of “fireflies” seemed to be “escaping” together in the same direction, and were told that they were competing against a “camera system” monitoring the boxes.

Before each task condition, participants were presented with eight demonstration trials. The first four demonstration trials were presented at a fast (6°/s) stimulus speed to help familiarise children with the task. The remaining four demonstration trials used the stimulus speed used throughout the rest of the experiment (1.5°/s). Participants were then required to pass a criterion of four consecutive correct responses to trials of 95% coherence. All participants met this criterion within 20 trials. Next, eight practice trials were presented to participants, with decreasing levels of coherence. Visual and verbal feedback was provided (for further details, see Manning et al., 2013).

Next, thresholds were estimated using the QUEST method (Watson & Pelli, 1983), with two staircases of 32 trials running interleaved and an additional 16 catch trials of 95% coherence (see Manning et al., 2013). No feedback regarding performance was provided during these trials, although the experimenter provided general encouragement throughout. The experimental trials were divided into four blocks of 20 trials, with a simulated graph of the “points” the participant and the “camera system” had obtained, which was randomly jittered around a fixed set of points for all participants (see Manning et al., 2014).

General procedure

The procedure was approved by the *[removed for blinding purposes]* Faculty Research Ethics Committee. Parents gave their informed consent and children provided their verbal assent. Children were tested in a dimly lit room and were seated 50 cm from the computer screen, which was fixed with a chin-rest. Participants were instructed to maintain central fixation throughout stimulus presentation, which was continuously monitored by the experimenter. Both conditions (limited and unlimited lifetime) were presented to children in a single session lasting approximately 30 minutes. The order of presentation of conditions was counterbalanced between participants. Children were administered the WASI, ADOS and acuity test in further sessions, resulting in two sessions lasting approximately 30 minutes each for TD children, and three sessions lasting approximately 30 to 40 minutes each for children with autism.

Data screening and transformation

All participants performed significantly above chance in the catch trials (i.e., responding correctly in 11 or more of the 16 catch trials). The percentage of incorrect responses to catch trials was used as an estimate of lapse rate for fitting psychometric functions (Treutwein, 1995). The data were bootstrapped and fit with a cumulative Gaussian function to obtain an estimate of the coherence level required for correct detection 75% of the time in log units (see Manning et al., 2013). Thresholds were then converted into linear units for analysis. Outliers were identified by converting data-points to z scores using the group means and standard deviations. Screening revealed an outlying point with a z score above 3 in the limited lifetime condition belonging to a child with autism. This point was retained in the dataset but replaced with a threshold value corresponding to a z score of 2.5 (Tabachnick & Fidell, 2007).

Results

An initial analysis of variance (ANOVA) confirmed that the order of conditions did not have a significant effect on motion coherence thresholds, $F(1, 58) = .01$, $p = .91$, and did not interact with group or lifetime condition (ps $\geq .79$). Similarly, the sex of participants had no significant effect on motion coherence thresholds, $F(1,58) = .32$, p = .57, and did not interact with group or lifetime condition (ps $\geq .30$). These factors were therefore removed from further analysis.

Examination of Figure 2 suggests that both children with autism and TD participants were more sensitive to coherent motion in the unlimited than the limited lifetime condition, but that there is considerable individual variability in both groups. The within-participants effect of lifetime condition was confirmed in a mixed design ANOVA on motion coherence thresholds, with group as a between-participants factor. As expected, higher motion coherence thresholds were obtained in the limited lifetime condition ($M = .22$; $SD = .11$) than in the unlimited lifetime condition ($M = .17$; $SD = .07$), $F(1, 60) = 12.91$, $p = .001$, $\eta_p^2 = .18$. However, the children with autism had similar thresholds ($M = .19$, $SD = .10$) as TD children ($M = .20$, $SD = .10$), $F(1, 60) = .28$, $p = .60$, and group did not interact with lifetime condition, $F(1, 60) = .05$, $p = .83$. Motion coherence thresholds were not related to age in either condition, in either group (ps $\geq .09$).

Insert Figure 2 about here

Discussion

In this study, children with autism and TD children aged 7 to 13 years were administered a motion coherence task under both limited and unlimited dot lifetime conditions. In line with adult studies (Braddick et al., 1998; Festa & Welch, 1997; Jackson et al., 2013), children had higher motion coherence thresholds when the dots moved with limited lifetime compared to when they moved with unlimited lifetime. Unexpectedly, however, the children with autism had comparable thresholds to the TD children, and were affected by limited lifetime to a similar extent as TD children.

The use of limited lifetime stimuli is normally justified as it precludes the tracking of single dots (e.g., Jackson et al., 2013; Milne et al., 2002). Therefore, it could be suggested that children are generally less sensitive to motion coherence stimuli in the limited lifetime condition as they are unable to rely on tracking strategies. However, it is unclear how tracking a single dot would lead to good performance at low levels of coherence. In this study, the mean threshold was approximately 0.17 (17% coherence) in the unlimited lifetime condition. If an individual was tracking a single dot on a trial with 17% coherence, there would be an 83% chance of the individual tracking a randomly-moving noise dot, which would be unlikely to lead to the threshold of 75% accuracy in performance. Furthermore, it could be argued that tracking cannot be completely ruled out unless the lifetime is limited to only two frames (Lee & Lu, 2010).

Another alternative is that the limited lifetime of dot stimuli introduces false correspondences between dots on successive frames, and that this correspondence noise elevates motion coherence thresholds (Barlow & Tripathy, 1997). Simmons et al. (2009) proposed that correspondence noise might present particular difficulties for children with autism. However, the findings of the current study suggest that children with autism and TD children are equally affected by the dot lifetime manipulation.

These findings are also in contrast with those measuring levels of autistic traits within the general population (Jackson et al., 2013). Jackson et al. (2013) presented adults with a motion coherence task in limited and unlimited lifetime conditions. The dots moved at a relatively slow speed (2.56°/s) and the lifetime of dots in the limited lifetime condition was 80ms – similar to the study reported here. However, Jackson et al. found that adults with high levels of autistic traits were more disrupted by limited lifetime stimuli than adults with low levels of autistic traits. In fact, high AQ-scorers showed *increased* sensitivity (i.e., lower thresholds) for unlimited lifetime stimuli compared to low-AQ scorers, and the extent of this group difference was reduced in the limited lifetime condition. This result is intriguing given that increased sensitivity to motion coherence stimuli has never been reported in individuals with a clinical diagnosis of autism (although see Foss-Feig et al., 2013, for a report of increased sensitivity to dynamic gratings in autistic individuals). The discrepancy between Jackson et al.'s results and the current results suggest that findings from individuals with high autistic traits may not generalise to individuals with a clinical diagnosis. Alternatively, the discrepancy could arise because different age groups were tested. However, it is unclear why children with high levels of autistic traits would be less affected by limited lifetime stimuli than adults with high levels of autistic traits. It is worth noting that, although we found no evidence of a developmental trend in this study, larger sample sizes will be needed to fully characterise the developmental trajectories of coherent motion processing in individuals with autism.

It remains a challenge to explain why children with autism did not have elevated motion coherence thresholds in this study, despite Manning et al. (2013) reporting elevated thresholds in children with autism using the same task (with limited lifetime stimuli). Perhaps the simplest explanation for the discrepancy between the results reported here and by Manning et al. concerns the participants tested. The children tested by Manning et al. were similar in their ranges of age and ability and the same inclusion criteria were applied to both datasets. However, it is increasingly apparent that not all children with autism have elevated motion coherence thresholds (Milne et al., 2002, 2006; Pellicano & Gibson, 2008). Discrepant results may therefore arise due to cohort differences. While between-participants variability is often increased in individuals with autism (e.g., Pellicano et al., 2005), the current results show a similar extent of variability in both groups. It remains a possibility that those children with autism who *do* show reduced coherent motion sensitivity are more susceptible to correspondence noise associated with limited lifetime stimuli (Simmons et al., 2009). Nonetheless, the results of the current study add to the mixed pattern of motion coherence findings in the literature and suggest that children with autism do not have general, pervasive difficulties with coherent motion perception. The lack of a clear-cut difference in motion coherence sensitivity between individuals with and without autism may reflect the fact that integration and segregation demands are confounded in motion coherence tasks (Dakin et al., 2005). Indeed, these factors may cancel each other out in children with autism, who may exhibit a profile of *enhanced* direction integration and *reduced* segregation of signal from noise compared to TD children (Manning et al., submitted).

In sum, this study shows that the motion coherence thresholds of children with autism are equally affected by a limited lifetime manipulation as those of TD children, suggesting that children with autism are *not* more affected by correspondence noise than TD children (c.f. Simmons et al., 2009). Unlike stimulus speed (Manning et al., 2013), duration (Robertson et al., 2012) and viewing conditions (Ronconi et al., 2012), dot lifetime does not appear to be an important parameter contributing to group differences in motion coherence sensitivity. This study provides further evidence against pervasive reductions in motion coherence sensitivity in children with autism.

Footnotes

1. Nine children with autism and four TD children had previously participated in the study reported by Manning et al. (2013). Excluding these participants did not change the pattern of results, so these participants were retained in the dataset to increase statistical power.
2. Twenty children with autism met criteria for an autism spectrum condition on both the SCQ and ADOS. We included all participants who met criteria on at least one of the measures in order to allow comparability with the results of Manning et al. (2013). Notwithstanding, the same pattern of results was obtained when excluding participants who did not meet criteria on both measures.

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Figure Captions

Figure 1. Schematic representation of a single trial structure. The fixation point and red (left) and blue (right) apertures remained on the screen throughout the trial. In this example, interval 1 is the target stimulus, containing a proportion of coherently moving dots, while interval 2 contains no coherently moving dots. Arrows are displayed for illustrative purposes, only.

Figure 2. Motion coherence thresholds for children with autism (dark circles) and TD children (light squares) in limited and unlimited lifetime conditions. Box-plots represent median scores and the interquartile range for each group. N.b. Data are presented with outliers replaced (Tabachnick & Fidell, 2007).

Figure 1 top

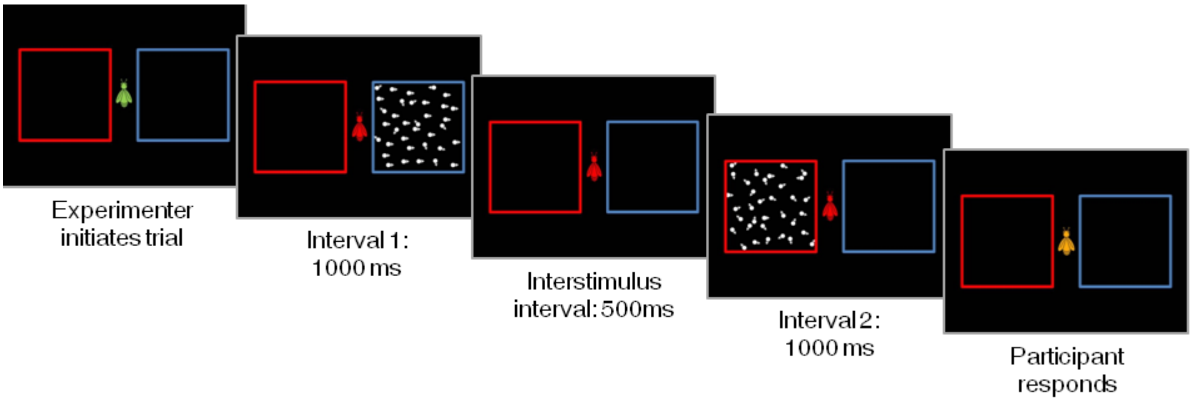
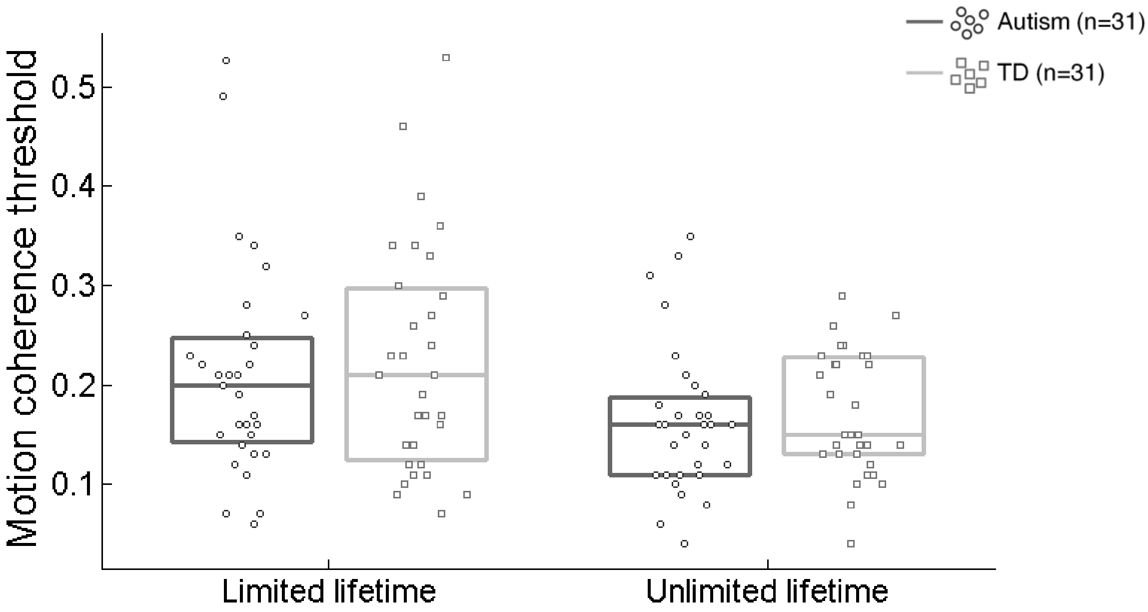

Experimenter
initiates trial
Interval 1:
1000 ms
Interstimulus
interval: 500ms
Interval 2:
1000 ms
Participant
responds

Figure 2 top


Autism (n=31)
TD (n=31)
Motion coherence threshold
0.5
0.4
0.3
0.2
0.1
Limited lifetime
Unlimited lifetime

Tables

Table 1. Participant characteristics

Measures	*Children with autism*	*Typically developing children*
N	31	31
Gender (*n* males: *n* females)	29:2	21:10
Age (years; months)		
Mean (SD)	10; 11 (1; 11)	10; 9 (1; 10)
Range	7; 3 – 13; 6	7; 9 – 13; 10
Verbal IQ		
Mean (SD)	98.68 (9.54)	108.00 (9.53)
Range	81 – 120	91 – 130
Performance IQ		
Mean (SD)	106.87 (13.41)	102.55 (13.68)
Range	83 – 137	78 – 131
Full-scale IQ		
Mean (SD)	103.03 (10.99)	106.06 (9.58)
Range	83 – 127	89 – 124
SCQ score		
Mean (SD)	24.47 (7.43)	3.14 (3.10)
Range	5 – 38	0 – 14
ADOS Social Affect		
Mean (SD)	9.43 (4.58)	
Range	1 – 17	
ADOS Restricted and Repetitive Behaviour		
Mean (SD)	2.04 (1.57)	
Range	0 – 6	
ADOS Total Score		
Mean (SD)	10.89 (5.44)	
Range	2 – 20	

Note. Verbal, Performance and Full-Scale IQ were assessed using the Wechsler Abbreviated Scales of Intelligence (WASI or WASI-II; Wechsler, 1999, 2011).
SCQ = Social Communication Questionnaire (Rutter et al., 2003).
ADOS = Autism Diagnostic Observation Schedule (Lord et al., 1999; Lord et al., 2012).