# SUPPLEMENTARY INFORMATION

**Supplementary Movie 1** complements Figure 1 in the main text. It shows:

- Top left quadrant: sample of a point-light animation presented to children;
- Top right quadrant: sample visual scanning data from a 2-year-old toddler with autism;
- Bottom left quadrant: sample visual scanning data from a 2-year-old, typically-developing toddler;
- Bottom right quadrant: sample visual scanning data from a 2-year-old, developmentally-delayed but nonautistic toddler.

Note: In these coded examples, Upright point-light animations are in red and Inverted point-light animations are in green. Stimuli were presented to children as white point lights against the black background as can be seen in the top left quadrant.

**Supplementary Movie 2** complements Figure 2 in the main text. It shows:

- Top left quadrant: sample of the pat-a-cake animation presented to children;
- Top right quadrant: sample visual scanning data from a 2-year-old toddler with autism watching the pat-a-cake animation;
- Bottom left quadrant: sample visual scanning data from a 2-year-old, typically-developing toddler watching the pat-a-cake animation;
- Bottom right quadrant: sample visual scanning data from a 2-year-old, developmentally-delayed but nonautistic toddler watching the pat-a-cake animation.

Note: In these coded examples, Upright point-light animations are in red and Inverted point-light animations are in green. Stimuli were presented to children as white point lights against the black background as can be seen in the top left quadrant.

**Supplementary Video 3** complements Figure 3 in the main text. More information about the method for measuring this effect is given below in the section, “Quantification of Audiovisual Synchrony”. Supplementary Video 3 shows the pat-a-cake animation, with color scaled values showing the level of audiovisual synchrony at each point-light.

Dark blue values correspond to little audiovisual synchrony or no audiovisual synchrony (e.g., in the area that would be the black background of the original animation). Red corresponds to the highest level of synchrony. The movie is played with audio at half-speed. Note that some point-lights are very synchronous (the hands, shown here during claps), while others are hardly synchronous (e.g., the feet).

**Participant Characterization**

*Participants in the Main Study*: 76 toddlers participated in the main study, comprising three groups (**Supplementary Table 1**): 21 toddlers with autism spectrum disorders (ASD), 39 typically-developing toddlers (TD), and 16 toddlers with developmental delays but without autism (DD). The ASD and TD groups were matched on chronological and nonverbal mental age equivalents obtained with the Visual Reception subtest of the *Mullen Scales of Early Learning*[1]. The ASD and DD groups were matched on chronological and verbal mental age equivalents as obtained through the average of Receptive and Expressive Language subtests of the *Mullen Scales of Early Learning*[1] . All children completed a comprehensive set of behavioral assessments as well as a physical exam and clinical genetics protocol.

Toddlers were included in the ASD group to the extent that they (1) met criteria for autistic disorder or autism spectrum disorder (ASD) on the *Autism Diagnostic Interview - Revised* (ADI-R) [2] (all ASD participants met criteria for autistic disorder); (2) met criteria for autistic disorder or ASD on the *Autism Diagnostic Observation Schedule*, Module 1 (ADOS)[3] (17 out of 21 met criteria for autistic disorder); (3) received a clinician-assigned diagnosis (independently, by two experienced clinicians upon review of available data including standardized testing and videotaped material of diagnostic examination) of either autistic disorder (14 of 21) or ASD (7 of 21); (4) had no known genetic syndrome; and (5) had neither hearing nor visual impairments.

Toddlers were included in the TD group to the extent that they (1) exhibited no developmental delays; (2) had no family history of ASD; (3) had no known genetic syndrome; and (4) had neither hearing nor visual impairments.

Toddlers were included in the DD group to the extent that (1) their developmental testing (as measured by the *Mullen Scales of Early Learning*[1]) exhibited either delays in two areas of development, each greater than 1.5 SDs below the mean, or a delay in one area of development, itself greater than 2 SDs below the mean; (2) had no family history of ASD; (3) had no known genetic syndrome; and (4) had neither hearing nor visual impairments.

**Supplementary Table 1**

| | **Autism Group[1]** | **Typically Developing Group[1]** | **Developmentally Delayed Group[1]** | $F_{2,73}$ values | **Pairwise Comparisons** |
|---|---|---|---|---|---|
| **N** | 21 | 39 | 16 | | |
| **Age** [2] | **2.21** (.54) | **1.99** (.66) | **2.02** (.62) | 0.852<br>NS[3] | ASD & TD = NS<br>ASD & DD = NS |
| **Nonverbal function** [4] | **2.00** (.95) | **2.10** (.81) | **1.73** (.76) | 1.102<br>NS | ASD & TD = NS<br>ASD & DD = NS |
| **Verbal function** [5] | **1.29** (.85) | **2.10** (.77) | **1.25** (.90) | 9.988<br>$p < .001$ | ASD & TD = $p < .001$<br>ASD & DD = NS |

[1] – Autism Group = ASD, Typical Controls – TD, Developmentally Delayed Controls – DD
[2] - Years;
[3] – NS = Not statistically significant.
[4] – Nonverbal function corresponds to age equivalent scores (in years) as obtained in the Visual Reception subtest of the *Mullen Scales of Early Learning*.
[5] - Verbal function corresponds to the average age equivalent scores (in years) of the Receptive and Expressive Language subtests of the *Mullen Scales of Early Learning*.

*Participants in the Follow-up Experiments*: There were two additional groups of participants recruited for the follow-up experiments. The first group was a new sample of 10 toddlers with ASD who completed follow-up experiments intended to test our audiovisual synchrony model in an *a priori* fashion. The protocol for recruitment and characterization was identical to that employed for the original sample of toddlers with ASD. The second sample of toddlers with ASD did not differ from the first sample in any of the characterization variables (**Supplementary Table 2**). The second group was a new sample of 12 typically-developing toddlers (TD). They completed the experiments in order for us to ensure that normative performance on the new tasks was comparable to results obtained for the original tasks (60.0% upright in the new animations, with $t_{49} = 0.72$ and $p = .48$ for comparison of these results with those of the original TD sample on the original animations). The two samples of TD toddlers also did not differ in any of the characterization variables (**Supplementary Table 3**).

**Supplementary Table 2**

| | **Autism Group 1** [1] | **Autism Group 2** [1] | $t_{29}$ values Significance |
|---|---|---|---|
| **N** | 21 | 10 | |
| **Age** [2] | **2.21** (.54) | **2.10** (.32) | 0.683 NS[3] |
| **Nonverbal function** [4] | **2.00** (.95) | **1.68** (.54) | -1.126 NS |
| **Verbal function** [5] | **1.29** (.85) | **1.13** (.67) | 0.942 NS |
| **ADOS (Social)** [6] | **8.86** (3.36) | **10.38** (2.87) | 0.488 NS |

[1] – Autism Group 1= ASD participants who completed the main study; Autism Group 2 = ASD participants who completed the follow-up experiments
[2] - Years;
[3] – NS = Not statistically significant.
[4] – Nonverbal function corresponds to age equivalent scores (in years) as obtained in the Visual Reception subtest of the *Mullen Scales of Early Learning*.
[5] - Verbal function corresponds to the average age equivalent scores (in years) of the Receptive and Expressive Language subtests of the *Mullen Scales of Early Learning*.
[6] - ADOS (Social): Scores for Social Cluster of the *Autism Diagnostic Observation Schedule*

**Supplementary Table 3**

| | TD Group 1 [1] | TD Group 2 [1] | $t_{49}$ values Significance |
|---|---|---|---|
| **N** | 39 | 12 | |
| **Age** [2] | **1.99** (.66) | **1.97** (.25) | 0.410 NS[3] |
| **Nonverbal function** [4] | **2.10** (.81) | **2.13** (.26) | -0.229 NS |
| **Verbal function** [5] | **2.10** (.77) | **1.88** (.41) | 1.254 NS |

[1] – TD Group 1 = Typical Controls who completed the main study; TD Group 2 = Typical controls who completed the follow-up experiments
[2] - Years;
[3] – NS = Not statistically significant.
[4] – Nonverbal function corresponds to age equivalent scores (in years) as obtained in the Visual Reception subtest of the *Mullen Scales of Early Learning*.
[5] - Verbal function corresponds to the average age equivalent scores (in years) of the Receptive and Expressive Language subtests of the *Mullen Scales of Early Learning*

**Motion Processing and Visual Integration**

Another interpretation of our results relates to the process of integrating visual stimuli of any kind: bringing fragments of information into coherent wholes [4]. Following this interpretation, failure to perceive biological motion might be a by-product of deficits in configural processing. Studies of motion coherence [5,6] have shown that children with autism require roughly 10% more motion signal before being able to discern a global direction of motion within a field of otherwise random motion, and this evidence should be considered alongside our results.

Several lines of evidence weaken the possibility that the present results are driven by difficulties in motion coherence thresholds. The primary evidence against this interpretation stems from the fact that detection of rigid coherent motion and biological motion are dissociable, and that impairment of the former does not imply that the latter will suffer. First, scrambling of point-light displays of humans and animals in which

configural information is entirely disrupted does not reduce inversion effects in the perception of biological motion [7]. Other studies have experimentally dissociated motion coherence from biological motion tasks in normal observers [8]. Second, sensitivity to the adaptive value of biological motion has been shown in much simpler organisms than humans [9,10], and is thought to facilitate learning via imprinting about the more specific features of motion of conspecifics as well as of a wide range of vertebrates [11]. Third, as noted earlier, successful perception of biological motion is possible in the face of severe impairments of other kinds of motion perception[12-14], even during disruptions of cortical activity in areas MT+/V5 by means of repetitive transcranial magnetic stimulation [15]. Fourth, the mechanisms that analyze biological motion do not integrate linearly over space and time with constant efficiency, as in other forms of complex motion, but instead adapt to the nature of the stimulus, making this form of motion quite different from others [16]. And fifth, in a study of 8-year-old children with autism [17], their deficits on a biological motion task contrasted with their preserved abilities in a motion integration task. Collectively, these and other studies highlight the uniqueness of biological motion as a class of motion stimuli relative to other forms of motion.

**References for Supplementary Information**

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