Supporting Information

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SI Text

Down Syndrome Number Study Materials and Methods. ***Participants.*** Of 19 infants/toddlers tested with Down syndrome (DS), 8 infants/toddlers were excluded because of inattention/restless behavior, and 2 infants/toddlers were outliers, because their looking times were significantly shorter than any other participant ($z > 2$). The remaining nine infants/toddlers were matched individually on chronological age and mental age to the nine participants with Williams syndrome (WS) reported on previously (1) using the Bayley Scale of Infant Development (Mental Scale) (2). All nine DS participants completed all of the tasks (participant characteristics are in Table S1). The findings from the small exact number discrimination task (see below) have now been replicated two times, showing that, despite the relatively small N values, we obtain the same within-syndrome results from different groups of atypical infants in the same age range. This finding suggests that the current DS group is representative of both the small and large number discrimination results.

Procedure. The infants were seated in a darkened room 60 cm away from a 97 × 56-cm monitor screen. They were either seated on a highchair in front of their parent or on their parent's lap. The parents were instructed to look at the back of their child's head or if the child was sitting on their lap, at the wall above the monitor. They were also asked to neither talk nor interfere during testing. The infants were observed by one of the experimenters who sat behind a curtain and watched them on a second monitor that was connected to a camera focused on the child's face. A picture-in-picture tool allowed the experimenter to simultaneously observe the child's face and the display at which the child was looking. Participants were presented with two tasks: small exact number (task 1) and large approximate number (task 2), with the order varied across participants.

Design. Both tasks consisted of nine familiarization trials and six test trials in which new and familiarized numerosities were presented in alternating order. In task 1, infants were either familiarized with two dots and tested on three dots or familiarized with three dots and tested on two dots. In task 2, infants were either familiarized with 8 dots and tested on 16 dots or familiarized with 16 dots and tested on 8 dots.

An attractive sound and spinning shape in the center of the screen was used to capture the infant's attention before the start of each trial. The trial started when the child was looking at the screen and ended after the child had looked away for 2 consecutive s or until a total of 10 s had passed, whichever occurred sooner.

Materials. For the purpose of the cross-syndrome comparison, identical stimuli to those stimuli used for infants with WS (1) were presented but in a different laboratory location. For task 1, the stimuli consisted of either two or three black dots on a 17 × 19-cm white background (Fig. S1). These stimuli changed to three or two dots, respectively, in the test trials. For task 2, the stimuli consisted of either 8 or 16 black dots on an 18 × 19-cm white background (Fig. S2), which changed to 16 or 8 dots, respectively. The dots were presented in various configurations and random order. The stimuli used in task 2 controlled for variables such as element size, display size, brightness, contour length, and display density (3). Eye tracking data were subsequently collected from some of the infants using a Tobii Infrared 1750 Eye Tracker (4).

DS Number Study Results. Although N values were necessarily small (because of the obvious difficulties of recruiting and testing very young children with genetic disorders), we replicated earlier work on small number discrimination with a new group of infants. All of the DS participants' looking times were coded offline frame by frame, with 22% of the trials also coded by a second person who was blind to the experimental hypotheses. Interrater reliability was high at 0.99 ($P < 0.001$).

Small exact number. Because no violations of normality occurred, two-tailed tests were used, except when directional effects were predicted. We had already shown in previous research that typically developing infants discriminate both small exact and large approximate number (5, 6), whereas WS infants discriminate small exact number but perform poorly on large approximate number (1, 7). To analyze the data from the current DS infants, a 3 × 2 repeated measures ANOVA was used for small exact number, with test pair (1–3) and trial type (novel and familiar) as the two factors. This analysis showed no main or interaction effects ($F_{2,16} = 2.89$, ns; $F_{1,8} = 0.63$, ns; $F_{2,16} = 0.10$, ns). The DS group mean of the first test trial (mean = 6.96 s, SD = 3.70) was also compared with the mean of the last three familiarization trials (mean = 6.18 s, SD = 3.18). For small exact number, the DS infants did not look significantly longer at the novel stimulus [$t(8) = 1.01$, ns]. Because N values were relatively small, we also carried out nonparametric tests [Friedman's ANOVA, Wilcoxon signed ranks test: $\chi^2_F(5) = 2.61$, ns; $z = 1.24$, ns], and the results were consistent with the parametric analyses. In summary, in contrast to infants with WS (1), infants with DS did not discriminate small exact numbers (Fig. S3). Before moving on to the findings with large approximate number, it is important to note that this finding replicates our previously published results (7) with a different set of DS infants, indicating that the current DS infant group is representative.

Large approximate number. For the large approximate number discrimination task for the infants with DS, a 3 (pair: 1, 2, or 3) × 2 (type: novel or familiar) repeated measures ANOVA yielded no main or interaction effects ($F_{2,16} = 1.99$, ns; $F_{1,8} = 0.29$, ns; $F_{2,16} = 0.30$, ns). These results were consistent with a nonparametric test [Friedman's ANOVA; $\chi^2_F(5) = 5.97$, ns]. However, in contrast to the WS infants, the DS infants looked significantly longer at the first novel stimulus for large approximate number (mean = 8.00 s, SD = 2.03) compared with the three familiarized stimuli that preceded it [mean = 6.62 s, SD = 1.56; $t(8) = 1.92$, $P = 0.046$, $r = 0.56$]. This result was confirmed by a nonparametric test (Wilcoxon signed ranks test: $z = 1.84$, $P = 0.033$, $r = 0.61$). Unlike small exact number and in contrast to infants with WS, the infants with DS showed, as predicted, an ability to discriminate between large numerosities (Fig. S3).

Fig. S4 illustrates the scanning patterns yielded by Tobii (4) over displays of 8 dots and 16 dots for an infant with DS and an infant with WS.

1. Van Herwegen J, Ansari D, Xu F, Karmiloff-Smith A (2008) Small and large number processing in infants and toddlers with Williams syndrome. *Dev Sci* 11:637–643.
2. Bayley N (1993) *Bayley Scales of Infant Development* (The Psychological Corporation, San Antonio), 2nd Ed.
3. Xu F, Spelke ES (2000) Large number discrimination in 6-month-old infants. *Cognition* 74:B1–B11.
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5. Xu F (2003) Numerosity discrimination in infants: Evidence for two systems of representations. *Cognition* 89:B15–B25.
6. Xu F, Arriaga RI (2007) Number discrimination in 10-month-old infants. *Br J Dev Psychol* 25:103–108.
7. Paterson SJ, Brown JH, Gsödl MK, Johnson MH, Karmiloff-Smith A (1999) Cognitive modularity and genetic disorders. *Science* 286:2355–2358.

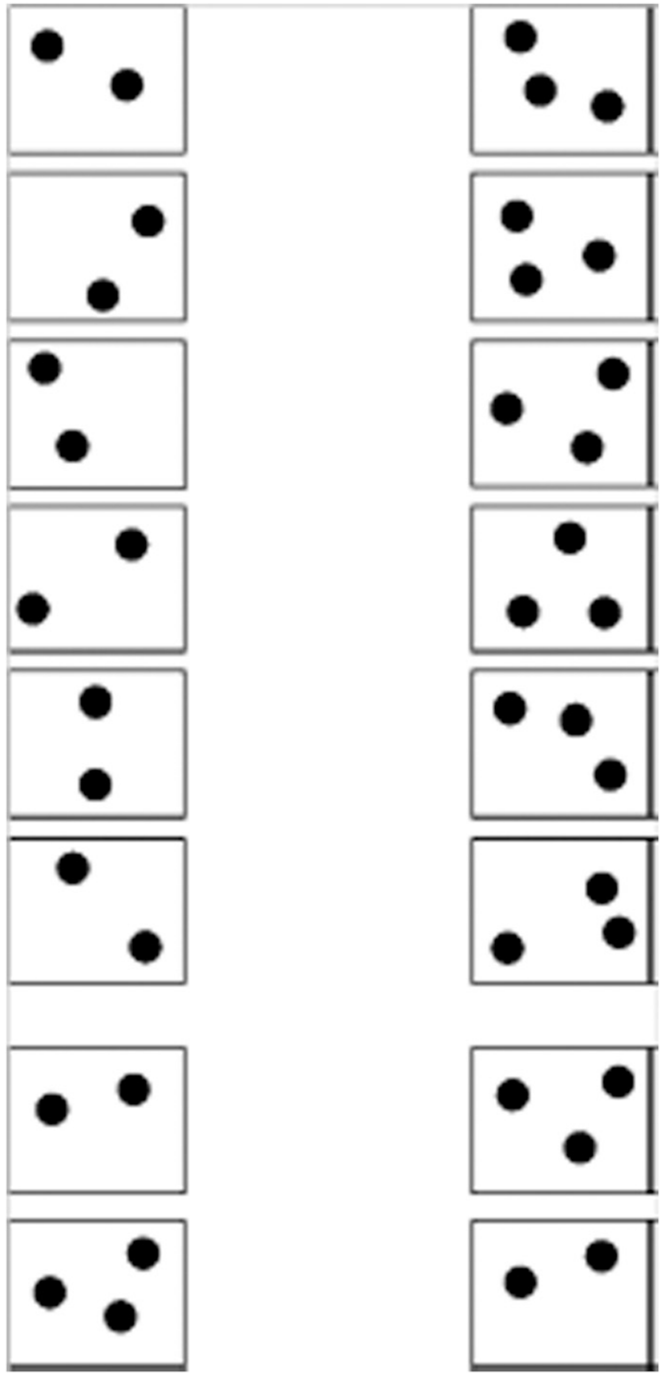

Fig. S1. Small number discrimination. Schematic representation of familiarization and test trials for each condition (2–3 or 3–2).

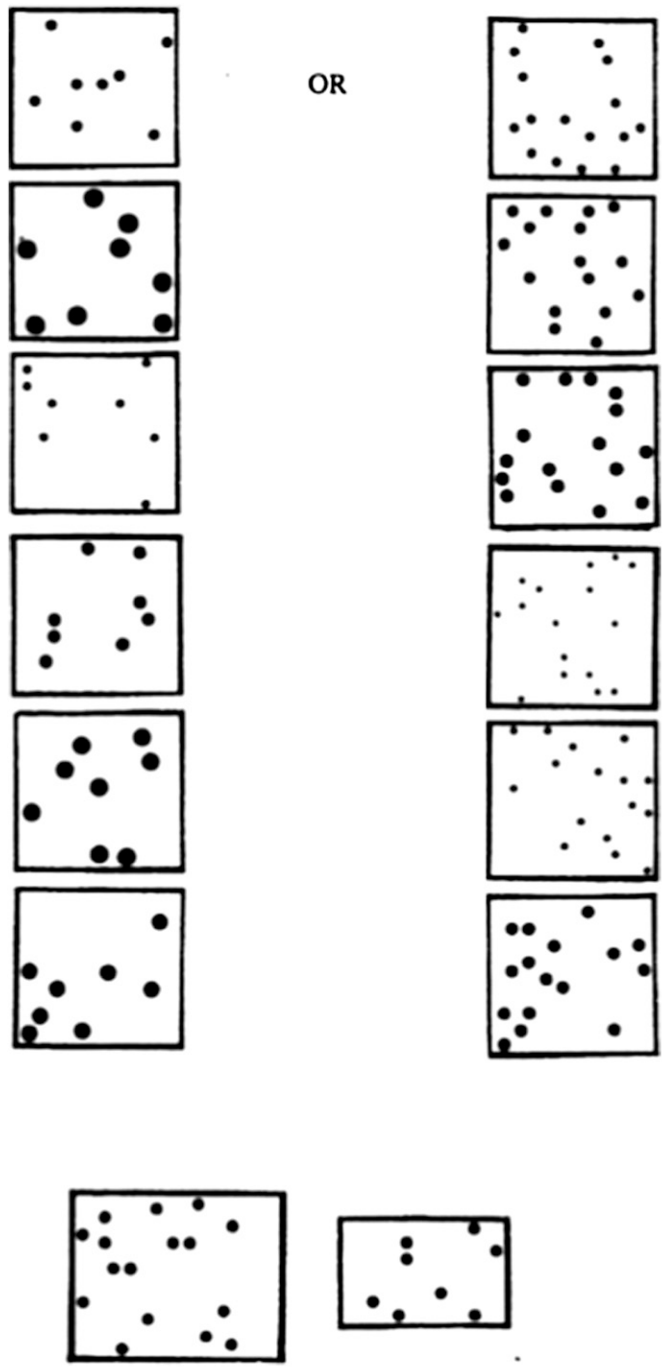

Fig. S2. Large number discrimination. Schematic representation of familiarization and test trials for each condition (8–16 or 16–8) from the work by Xu and Spelke (3).

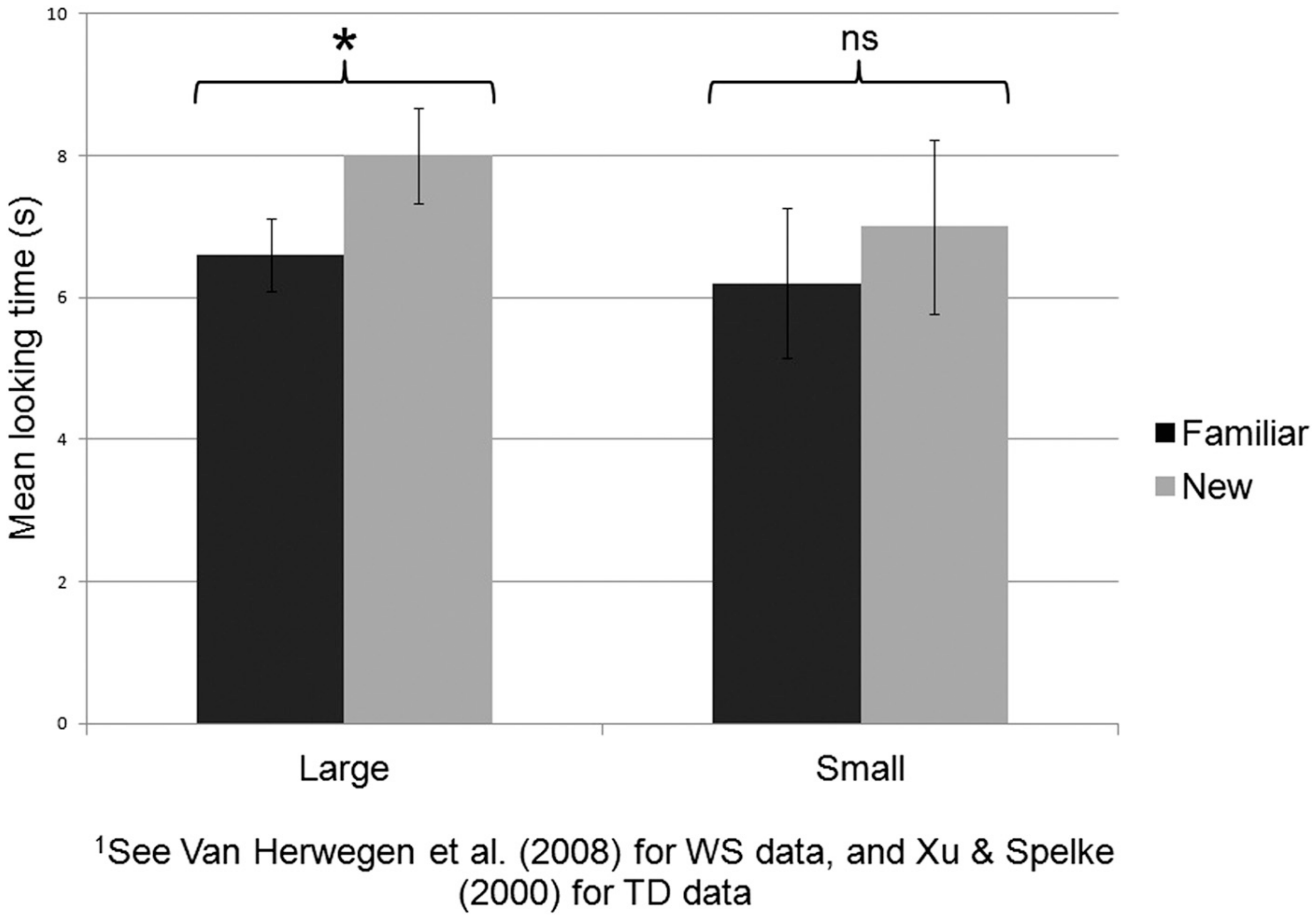

Fig. S3. Mean looking times for the last three familiarization trials and the first (new) test trial for large and small numerosities in DS. Error bars represent the SEM. WS data are in ref. 1, and typically developing data are in ref. 3. *$P < 0.05$.

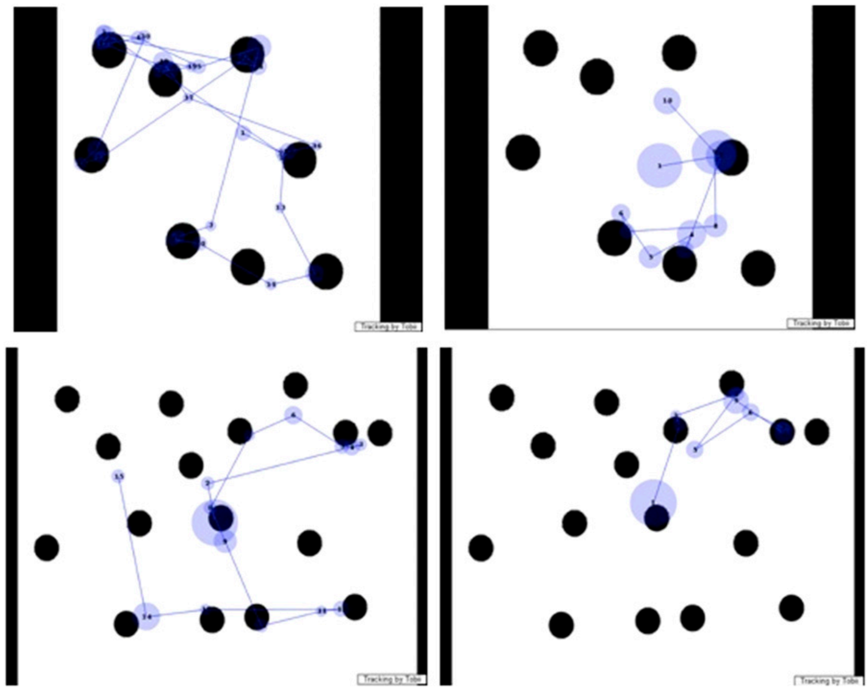

Fig. S4. Examples of infant scanning patterns for 8 and 16 dots (*Left*, infant with DS; *Right*, infant with WS).

Table S1. Participant characteristics

Group	*N*	Sex (male:female)	Chronological age (months)	Mental age* (months)	Mother's occupation†	Father's occupation†	Mother's education‡	Father's education‡
DS	9	5:4	27	15	2.0	1.4	3.0	2.5
WS	9	5:4	36	22	2.0	1.7	3.6	3.8

*Mental age was measured using the Bayley Scales of Infant Development (ref. 1).
†Parental occupation was rated according to the Social Occupation Classification on a four-category scale (ref. 2): 1, higher managerial or professional; 2, intermediate; 3, routine/semiroutine; 4, unemployed over 6 mo.
‡Parental education was rated using the following scale: 1, postgraduate; 2, higher education degree; 3, further education; 4, high school A levels; 5, General Certificate of Secondary Education (GCSE); 6, no qualification. There were no significant differences between groups on parental occupation or parental education (all P = ns).

1. Bayley N (1993) *Bayley Scales of Infant Development* (The Psychological Corporation, San Antonio), 2nd Ed.
2. UK Office for National Statistics (2010) Standard Occupational Classification 2010*. The National Statistics Socio-economic Classification User Manual* (Basingstoke: Palgrave Macmillan), vol 3.