Symposium Title: Object Exploration and Developmental Outcomes in Infants and Young Children with Down Syndrome

Chair: Deborah J. Fidler¹

Discussant: Anna Esbensen²

Overview: Down syndrome (DS) is the most prevalent neurogenetic disorder contributing to intellectual disability, occurring in 1:691 live births (Parker et al., 2010). An additional copy of chromosome 21 causes most cases of DS, also known as trisomy 21 (Haydar & Reeves, 2011). Additionally, this neurogenetic syndrome results in individuals having a high probability of demonstrating a behavioral phenotype, a specific pattern of competencies and challenges relative to mental age. While there is a great amount of individual variability in how it manifests, the DS behavioral phenotype includes relative proficiencies in aspects of visual processing, receptive language, and core social-relatedness; and relative weaknesses in expressive language, verbal processing, aspects of executive function including verbal working memory, aspects of fine and gross motor functioning, planning, and adaptive functioning. Intellectual disability occurs in almost all individuals with DS, presenting a critical intervention challenge that is currently unmet.

Intellectual disability in DS is associated with alterations in brain structures and functions that are detectable from infancy. Therefore the DS phenotype begins in utero, and extant behavioral research supports the early development of the DS phenotype (Edgin et al., 2015). It is well-established that experiences in infancy and childhood shape developmental outcomes in both typically developing children (Adolph, 2008) and children with neurogenetic disorders, such as DS (Ulrich, Ulrich, Angulo-Kinzler, & Yun, 2001). Recent advances in infant science research have highlighted that purposeful, exploratory actions on objects specifically mediate infant learning (Libertus & Needham, 2010; Somerville, Woodward, & Needham, 2005; Needham, Barrett, & Peterman, 2002). However, there is a paucity of data using infant science paradigms and methodology to comprehensively characterize the early emergence of the DS phenotypic profile. The presentations in this symposium will address this gap in our knowledge regarding early object manipulation and outcomes in infants with DS. The first presentation will examine the reasons for the observed differences in object exploration between infants with DS and TD infants so that we can design interventions to help ameliorate or reduce delays and produce a positive impact on learning in infants with DS. The second presentation will evaluate the contributions of visual perception and efficient grasp execution to cognitive development in infants with DS. The third presentation will use Latent Profile Analysis to examine patterns of early exploratory behavior in infants with DS and identify associations between profiles of early exploratory behavior and concurrent cognitive and communication skill development. The findings from these presentations will emphasize the role of engagement with the environment to optimize developmental outcomes in infants with DS.

Paper 1 of 3

Title: Object Exploration in Infants with and without Down Syndrome

Authors: Maninderjit Kaur³, Amy Needham³

Introduction: Object exploration is critical for infants and young children to learn about objects. However, infants with Down syndrome (DS) tend to explore objects less actively than typically developing (TD) infants (Landry & Chapieski, 1989). DS is the most common chromosomal disorder and the leading cause of intellectual disabilities in children. Infants with DS typically have cognitive and motor deficits which could be related to each other: current research in TD infants shows cascading effects of motor development on cognitive and social development (Bornstein, Hahn, & Suwalsky, 2013; Libertus & Needham, 2011). The current study is part of our effort to fully understand the reasons for the observed differences in object exploration between

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infants with DS and TD infants so that we can design interventions to help ameliorate or reduce these differences and produce a positive impact on learning in infants with DS.

**Methods:** Sixteen infants with DS between 7 and 54 months of age and an additional 16 mental-age matched typically developing (TD) infants participated in the study. Infants were seated on caregiver’s lap across a table and the experimenter presented three different toys – a sounding piano, a lighting buzzer, and a play center with both light and sound plates. Infants were presented these objects twice (T1 = 1st presentation, T2 = 2nd presentation). All three toys required tapping on the piano keys or tapping on the plates of the buzzer and play center to activate them. So, we coded for the percent duration of infants’ tapping using their fingers or their whole hand while exploring the toys. Further, we coded for infants’ successful activation of the toys, i.e., producing sound from piano, light from buzzer, and light/sound from play center.

**Results:** For the tapping data, we conducted a repeated measures ANOVA with Presentation (T1 and T2), Object (piano, buzzer, play center), Body part (finger, hand) as within-subjects factors, and Group (TD, DS) as the between-subjects factor. The ANOVA revealed significant 3-way interactions between Object x Body-part x Group, and Object x Presentation x Group. The post hoc t-tests indicated that infants in both the groups showed appropriate use of body part while tapping the piano, i.e., an isolated finger rather than their whole hand to press the piano keys. But we saw a difference in how the two groups of infants interacted with the play center: the TD infants showed an effective approach of using the whole hand to tap on the relatively larger plates of the play center compared to infants with DS who used their fingers more than their whole hand while exploring the play center. Lastly, the TD infants showed less tapping of the objects during T2 compared to T1 perhaps highlighting a typical learning behavior, i.e., habituation, where infants tend to reduce their exploration of objects with repeated presentations or familiarity with objects.

For the activation data, we conducted another repeated measures ANOVA with Presentation (T1 and T2) and Object (piano, buzzer, play center) as within-subjects factors, and Group (TD, DS) as the between-subjects factor. This analysis indicated statistical trends for a main effect of object and an interaction between Presentation and Group. The post hoc analysis for the 2-way interaction indicated that TD infants were more successful in activating the objects during T2 compared to T1, whereas infants with DS showed no differences in object activation between the two presentations.

**Discussion:** Overall, infants with DS did not modify their exploration based on the object size and properties, and they continued to use ineffective finger tapping to explore the relatively larger plates of the play center. Additionally, TD infants showed less exploration or tapping of objects during the second presentation, but they were still more successful in activating the objects compared to infants with DS. Our interpretation of this pattern of results is that TD infants were able to learn about the objects from their first interaction with them, and they were able to extend this learning from the first to the second presentation of the objects. On the other hand, infants with DS were unable to extend their learning in between the two presentations, indicating that they may have needed more time or some scaffolding from an adult to learn the most advantageous ways of acting on new objects.

**References/Citations:**


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Title: The Role of Perception and Motor Action in the Cognitive Development of Infants with Down Syndrome

Authors: Lisa A. Daunhauer¹, Deborah J. Fidler¹, Emily Sch worer³, Amy Needham³

Introduction. Perception and motor action facilitates infant cognitive development. Typically developing (TD) infants visually anticipate an object’s structure prior to physically grasping it (Fagard, 2000) and manipulate objects to understand their properties and enact complex motor actions on the world (Needham, 2000). A very limited amount of research on infants with developmental disabilities suggests similar findings (Libertus & Hauf, 2017). Infants with Down syndrome (DS) are predisposed to phenotypic outcomes including relative competencies in visual perception, significant challenges in motor abilities (Daunhauer & Fidler, 2010), and intellectual disability notable for declines in IQ across childhood (Hodapp et al., 1999). In this study, we used an infant science paradigm to evaluate the contributions of visual anticipation and motor action (efficient grasp execution) to cognitive development in infants with DS.

Methods. Infants with DS (n= 55; M chronological age= 9.77, SD= 3.71; M mental age = 6.86, SD = 2.80) participated in a standardized developmental assessment and a motor cognition task (Barrett et al., 2008). Examiners presented participants with four similar-sized balls, one at a time for approximately 30s, using an open palm to avoid demonstrating grasps for this task. Each ball had unique properties including (1) rigid with craters, (2) rigid with round protrusions; (3) flexible with rubber fins (“Squidgee”); and (4) flexible, rubber pom-pom (“Koosh”). Visual anticipation was coded as latency to initial object contact (recorded in seconds) following each object presentation. Grasp efficiency was coded as the frequency of object grasps demonstrating adaptation to the balls’ specific properties (e.g., grasping crater ball with fingers in craters). The sample was coded for reliability, and average kappas were high (Cohen’s Kappa = .82) for 38% of the sample.

Results. There were no significant within-group results across conditions for both visual anticipation and grasp efficiency. Composite scores were created for visual anticipation and grasp efficiency by averaging performance across the four trials for each. Pearson correlations indicated significant relationships between cognitive development and both visual anticipation (r (47) =-.65, p ≤ .001) and grasp efficiency (r (47) =.78, p ≤ .001), as well as between visual anticipation and grasp efficiency (r (47) =-.56, p ≤ .001). To better understand the contributions of these factors while controlling for maturation, cognitive development was regressed on chronological age, visual anticipation, and grasp efficiency. The regression was significant [adjR² =.72, (F (3, 47) = 40.55, p ≤.001)]. Furthermore, visual anticipation (b=-.23, p=.023) and grasp efficiency (b=.37, p=.003) explained a significant amount of the variance in cognitive development even when controlling for chronological age (b=.38, p=.003).

Discussion. The findings indicated that spending less time using visual anticipation and demonstrating the more frequent use of efficient grasps adapted to objects’ properties predicted more competent cognitive developmental status in infants with DS, even when controlling for maturation. This study also emphasizes that the integration of visual perception and motor action emerges in early infancy in DS and this finding corresponds with research on TD infants (Barrett et al., 2007). Furthermore, broader research on children with TD (e.g., Pitchford et al., 2016) and those with disabilities (Kim et al., 2016) has found similar associations with visual motor integration and both cognitive function and academic achievement. Some researchers have hypothesized that these relationships reflect shared underlying neural structures and functions between the cerebellum and prefrontal cortex (Pitchford et al., 2016). Taken as a whole, this study suggests that early intervention programs that support visual motor integration may elicit more optimal cognitive outcomes in this population.

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Title: Exploratory Behavior and Developmental Skill Acquisition in Infants with Down Syndrome

Authors: Deborah J. Fidler, Ph.D., ‡ Emily Schworer, M.S., ‡ Mark Prince, Ph.D., ‡ Elizabeth Will, Ph.D., ‡ Amy Needham, PhD ‡ & Lisa Daunhauer, Sc.D. ‡

Introduction: Early exploratory behavior serves as the experiential context for many aspects of infant development (Gibson, 1988). During early object exploration, in particular, infants have the opportunity to formulate representations of object properties, which support foundational learning about objects as well as decisions about how best to utilize those objects for play and problem-solving. The developmental consequences, therefore, of impoverished early exploratory behavior in infancy are potentially far-reaching. Certain neurodevelopmental disorders, including Down syndrome (DS), place infants at risk for impoverished exploration (MacTurk, Vietze, McCarthy, McQuinston, & Yarrow, 1985), but a direct link between exploration and overall developmental functioning in neurodevelopmental disorders has not yet been established. In this study, we use Latent Profile Analysis to examine patterns of early exploratory behavior in infants with DS and we identify links between profiles of early exploratory behavior and concurrent cognitive and communication skill acquisition.

Methods: Forty-five infants with DS (mean chronological age = 9.58 months; SD = 3.62) and their caregivers participated in this study. Infants were assessed using the Bayley Scales of Infant Development-III (Bayley, 2006) and a 1-minute Exploration Trial. Thirty percent of the sample was independently coded for reliability and average kappas were high (Cohen’s Kappa = .93). Exploration profiles were derived using Latent Profile Analysis (LPA) with three indicator variables: the calculated percentage of time that infants spent in visual exploration, manual exploration, and oral exploration during the exploration task. To examine the predictive value of latent profiles and developmental outcomes, we used the BCH method for continuous variables and the DCAT method for dichotomous variables (Asparouhov & Muthen, 2014; Bakk, & Vermunt, 2016).

Results: The 2-profile solution provided the best overall model fit to the data (Lo-Mendell-Rubin = 32.24, p = .05). Examination of the Lo-Mendell-Rubin tests indicated that the 2-profile model was an improvement over the 1-profile model, but a 3-profile model was not an improvement over the 2-profile model. The two profiles of the best fitting model can be described as an Active Exploratory profile (57.78% of the sample) and a Passive Exploratory profile (42.22%). In terms of percentage of time engaged in exploration during the task, the passive profile was associated with moderate visual exploration (51.09% of the trial), low manual exploration (20.47% of the trial), and minimal oral exploration (.43% of the trial). The Active Exploration profile was associated with moderate levels of visual exploration (59.78%), high levels of manual exploration (78.84%), and moderate levels of oral exploration (20.04%). The Active Exploration profile was associated with higher Cognitive, Expressive Communication, and Receptive Communication scores (see Table 1).

Discussion: This study is among the first to examine profiles of early exploratory behavior in infants with DS and their association with developmental skill acquisition. LPA revealed two latent profiles of infant visual, manual, and oral exploration, one more active and one more passive. Using auxiliary analysis within an LPA framework, a statistical link was observed between exploration profiles and concurrent cognitive and communication developmental skill acquisition. Though the lack of temporal precedence precludes making conclusions regarding causality, these data are consistent with the literature regarding the link between exploratory behavior in infancy serving as an important context for both cognitive and communicative development. Findings from this study suggest that distinct patterns of exploratory behavior are observable even in infancy in DS, with some infants demonstrating a greater degree of early engagement with their environments, which can serve as a richer platform for developing foundational communication, cognitive skills, and knowledge about the physical world.

Table 1.

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<th>Auxiliary Variables</th>
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<td>Mean (SD)</td>
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Bayley Cognitive raw score | 22.68 (1.84) | 30.06 (1.47) | 9.39 (.002) | .47
Bayley Expressive Communication raw score | 6.09 (.57) | 8.58 (.70) | 7.32 (.007) | .40
Bayley Receptive Communication raw score | 7.57 (.46) | 9.65 (.59) | 7.31 (.007) | .40

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References

