Performance During Object Retrieval Tasks in Young Children with and without Down Syndrome

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Abstract

Object retrieval skills requiring means-end exploration are delayed or impaired in infants with Down Syndrome (DS). The current study examined the role of ecological constraints, i.e., task difficulty and environmental context on the object retrieval skills of young children with DS. Thirteen children with DS (31.55 ± 4.14 months) and 13 mental-age matched Typically Developing (TD) children (17.31 ± 1.64 months) completed three tasks involving retrieving a toy from a transparent box (task 1), an opaque box (task 2), and a transparent box hidden inside an opaque box (task 3). Both DS and TD group performed similarly for the simpler task 1; but for task 2 and task 3, the DS group had less success rate, fewer use of complex asymmetric hand actions, and/or longer planning and execution times compared to TD group. Future studies should examine the developmental trends and specificity of means-ends exploratory behaviors in children with DS.

INTRODUCTION

Exploring and playing with objects are integral parts of early development and infants show substantial changes in exploratory behaviors over the first few years of life (Belsky & Most, 1981; Bornstein et al., 2013). In contrast, children with developmental disabilities such as Down syndrome (DS) tend to be less engaged with objects and explore them less actively (de Campos et al., 2013; Fidler et al., 2019; Landry & Chapieski, 1989; MacTurk et al., 1985; Venuti et al., 2009). DS is one of the most common chromosomal disorders with an estimated prevalence of 1 in 700 live births (Parker et al., 2010). Atypicalities in object play in individuals with DS are evident as early as the infancy period and persist throughout the childhood period (de Campos et al., 2010; 2011; 2013; Fidler, Hepburn, et al., 2005; Fidler et al., 2014). For example, infants with DS between 4- to 6-month-old showed less successful grasping and fewer exploratory behaviors including reaching, banging, and rotating during an object exploration task compared to chronological age-matched TD infants (de Campos et al., 2010; 2013).11Although infants with DS are documented to show less active or reduced exploration of toys, recent work by Fidler et al (2019) indicates that this characterization of less active exploration may accurately reflect only a subset of infants with DS. Similarly, school-aged children with DS were observed during a 2-minute free play with random set of toys such as plastic coins, bracelet bands, and paper cups (Fidler et al., 2014). During the play session, children with DS were less likely to initiate actions on new toys (i.e., previously unexplored toys) and less likely to show novel functional actions (i.e., previously undemonstrated functional actions) compared to mental-age matched TD children and children with other development disabilities (Fidler et al., 2014). Overall, infants and children with DS show significant delays in their ability to meaningfully explore objects compared to mental-age matched TD children.

Performance during Object Retrieval Tasks in Typical Infants and Infants with DS

In this study, we are extending our current knowledge about object play in children with DS to a specific functional skill, *object retrieval* . Object retrieval requires means-ends exploration, i.e., planning and executing different strategies as a means to achieve an end goal of toy retrieval, and has been extensively studied in the typical population using tasks such as retrieving an object from a concealed container or pulling a cloth to retrieve a toy located at the end of the cloth (Piaget, 1953; Willatts, 1999). In TD infants, the ability to successfully retrieve objects usually emerges during the end of first year, however, infants continue to refine this skill in the second year of life. Bruner (1970) examined the development of object retrieval during the first 2 years of life and indicated that infants younger than 6-8 months old were unsuccessful in the task. Older infants between 9-17 months were successful but infants seem to refine this skill with increasing age such that infants between 9 and 11 months used unimanual strategies, infants between 12 and 14 months used bimanual strategies, and infants between 15 and 17 months used complex (more refined) bimanual strategies to retrieve the toy (Bruner, 1970). Means-ends exploration and object retrieval skills depend on the motor (Bojczyk & Corbetta, 2004), perceptual (Babik et al., 2019), and cognitive skills of children (Willats, 1999; Sommerville & Woodward, 2005). Furthermore, means-ends exploration is a crucial development skill and is closely associated with the development of goal-directed behaviors, problem solving skills, and intentionality (Willats, 1999; Babik et al., 2019).

In contrast to the TD infants, there is a relative dearth of studies on the development of object retrieval skills in infants and children with DS (Schworer et al., 2020; Fidler, Hepburn, et al., 2005). When compared to TD controls, 4- to 12-months old with DS took longer to execute strategies such as pulling a cloth and grasping a toy while trying to retrieve a toy located at the end of a 12-inch cloth (Schworer et al., 2020). Similarly, 2- to 3-year-old children with DS produced fewer effective strategies while trying to retrieve a toy/snack from a clear plexiglass box with an opening on one side (Fidler, Hepburn, et al., 2005). Furthermore, object retrieval strategies were associated with the non-verbal behaviors of children with DS, such that children with poor retrieval strategies (e.g., more reaching failures) showed fewer non-verbal behaviors in social contexts (e.g., less looking/pointing at objects and less requesting of social routines like tickling) (Fidler, Philofsky, et al., 2005). Overall, existing evidence indicates that infants and children with DS are less successful than their TD peers in means-ends exploration tasks requiring the retrieval of hidden objects.

Factors Impacting Object Retrieval Skills in Children

From the Ecological perspective, *person-task-contexts* interact with one another to influence performance (Gibson & Pick, 2000). Therefore, object retrieval skills could be impacted by the presence/severity of a health condition (*person level*), the complexity and difficulty of the task (*task level*), and the environmental set-up or setting (*context level*). Specifically, task complexity during object retrieval tasks could result from the number of steps (Goubet et al., 2006), use of additional tools (Poulson et al., 1989; Bojczyk & Corbetta, 2004), or the need for bimanual coordination/dissociation to retrieve the toy (Diamond 1988; 1991). Goubet et al. (2006) indicated that older 18-month-old TD infants were more successful during tasks requiring greater number of steps to retrieve toys (e.g., pulling a mat followed by lifting a box and opening locked devices) compared to younger 9-month-old infants. Similarly, the environmental set-up such as the degree of transparency of the boxes involved in the task could impact infants' performance (Bojczyk & Corbetta, 2004). Bojczyk & Corbetta (2004) provided repeated exposure to object retrieval tasks using semitransparent or opaque boxes to TD infants beginning at 6.5 months of age. These infants showed earlier learning (and success) in the task for infants exposed to a semitransparent box compared to an opaque box. In contrast to the TD literature, there is lack of studies examining the impact of task and/or context on the object retrieval skills of infants and children with DS. The research we present here aims to begin to fill this gap.

Goals of the Study

The primary goal of the current study is to examine the impact of task difficulty and environmental context on the object retrieval skills of young children with DS. Children were presented with three tasks requiring retrieving a toy from a transparent box (task 1), an opaque box (task 2), and a transparent box within an opaque box (task 3). Specifically, task 1 was the baseline with no additional task and/or contextual complexity, whereas task 2 had contextual complexity, and task 3 had both task + contextual complexity. We hypothesized that compared to the mental age-matched TD group, children with DS will have similar success in the simple task of retrieving toy from a transparent box (task 1), however, during task 2 and 3, children with DS will perform poorly compared to TD controls as assessed using the success rate, use of bimanual strategies, and/or completion time.

METHODS

Participants

Twenty-six children participated in the study with 13 children each in the DS (chronological age = 31.55 ± 4.14 months; mental age = 14.75 ± 1.84 months) and TD group (chronological age = 17.31 ± 1.64 months; mental age = 17.39 ± 1.96 months; Table 1). Parents of children in the DS group submitted a medical record confirming the genetic diagnosis of Trisomy 21. Parents of TD infants completed a brief screening to confirm absence of any birth/family/developmental history of delays. Additionally, all parents confirmed the absence of any significant physical/visual/hearing impairments which would impair child's participation in the study. Participants in the DS group were recruited from local organizations, centers, and schools. TD infants were recruited through birth records obtained from the state and through word of mouth. The group demographics including the age, sex, ethnicity, and parents' age and education are provided in Table 1. Both groups were similar in terms of mental age, sex, ethnicity, and parents' age, but differed in terms of parents' education (Table 1). The parents in the DS group had fewer years of education compared to the parents in the TD group ($p < 0.05$, Table 1). All parents signed the consent form approved by the university's Review Board before participating in the study.

Experimental Task

Children sat on their parent's lap at a semi-circular table, with the experimenter seated across the table and directly in front of the child. Each child completed a series of object retrieval tasks, which involved retrieving a small toy figurine from a transparent box (Task 1), opaque box (Task 2), and a transparent box nested within the opaque box (Task 3; see Figure 1 for boxes and toy figurine used in the study). For task 1 and 2, children would have to make manual contact with the box, open the lid of the box, and remove the toy from the box. For task 3, children would open the lid of opaque box, remove the transparent box from the opaque box, and then open the lid of the transparent box to retrieve the toy. Each task started with the experimenter showing an animal toy figurine to the child to gage attention, followed by placing the toy in the box in front of the child. The box was then presented to the child by saying "Can you get the toy?". If the child seemed disinterested, the experimenter would reorient them to the task by repeating the verbal prompt or pointing to the toy in the box. The task would end upon toy retrieval or after 60 seconds of exploration with the box(es). If the child was unsuccessful to retrieve the toy after 60 seconds, the experimenter would open the lid and/or take the toy out of the box. One child in the TD group and 2 children in the DS group were missing data for task 3.

Behavior Coding

The experimental tasks were coded for four behavioral measures: success, adult assistance, hand actions, and time to plan and execute the task. Each behavior measure was scored by two coders to establish interrater reliability for 30% of the dataset. Interrater correlations were > 0.85 for all the measures (Success = 1, Assistance = 0.87, Hand actions = 0.88 to 0.96, Planning time = 0.92, Execution time = 0.85).

Success : Success was defined as the child opening the lid of the box and taking the toy out. If after opening the lid, children used other strategies such as vigorously shaking the box, knocking over the box, or dumping the contents onto the table, it was considered successful. Additionally, if children required partial assistance from the adult experimenter (see definition below) to retrieve the toy, it was scored as success. We are reporting on the percentage of children in the DS and TD group who succeeded in the experimental tasks.

Adult Assistance : Adult assistance was defined as the physical help provided by the experimenter to retrieve the toy from the box. Assistance was scored as 0 (no assistance) if the child independently retrieved the toy from the box, 1 (partial assistance) if the child required help from the experimenter to stabilize the box while they opened the lid and/or took the toy out of the box, and 2 (total assistance) if the child was unable to complete the task on their own and required help to open the lid and take the toy out. We are reporting on the percentage of children in the DS and TD group who required no, partial, and total assistance for the three tasks.

Hand actions : Child's use of hands was scored as unimanual if they used only one hand (right or left) and bimanual if they used both hands while completing the task. Bimanual actions were further categorized as symmetrical or asymmetrical. Symmetrical bimanual actions indicated using two hands to perform a same action, e.g., opening the lid of a box with both right and left hand. Asymmetrical bimanual actions indicated using two hands to perform different actions, e.g., holding the box with one hand and opening the lid with other. We are reporting on the total frequency of unimanual, symmetric bimanual, and asymmetric bimanual actions for the experimental tasks.

Planning and execution time : Planning time was the time required to plan actions and was scored as the time taken by the child to make first manual contact with the box after the experimenter placed the box on the table. Execution time was the time required to complete the task and was defined as the time taken to open the lid of the box after making first manual contact with the box. Execution time was not scored for children who were unsuccessful in opening the lid and/or required total assistance. We did not consider the time taken to take the toy out of the box within the execution time as there was lot of variability in the strategies used to take the toy out of the box. For example, some children quickly dumped the toy on the table after opening the lid vs others took time to carefully scoop the toy out using their fingers. We are reporting on the planning and execution time in seconds for the three tasks and the total time.

Bayley Test of Infant Development- 3rdEdition (Bayley-III)

The Bayley-III is a standardized measure to assess the cognitive, motor, language, socio-emotional, and adaptive behaviors of infants and young children between 1 and 42 months (Bayley, 2006). It is reported to have high reliability (internal consistency among domains ranges between 0.83 and 0.93) and moderate validity (confirmatory factor analysis of domain structure ranges between 0.50 and 0.79). We used the cognitive subtest of Bayley-III to match the children between the DS and TD group based on their cognitive developmental skills. The cognitive subtest assesses the problem-solving, concept formation, and memory through tasks such as completing puzzles, matching, and counting. The subtest raw scores can be converted to scaled scores and age equivalents based on the scoring norms. The age equivalents of the cognitive subtest were used to match the children across the two groups (Table 1). One child with DS did not complete the cognitive subtest due to non-compliance with the experimenter during the session; their experimental data was included in the final sample.

STATISTICAL ANALYSIS

For success and tester assistance, regression analysis was conducted to determine the effect of group on task performance. A binary logistic regression was conducted for the dichotomous variable success and a multinomial regression analysis was conducted for tester assistance separately for each experimental task. For hand actions and time to plan/execute, nonparametric tests (Mann–Whitney U) were used because the data was not normally distributed using the Shapiro-Wilk test of normality ($p < 0.05$ across comparisons). Significance was set at $p < 0.05$ and p -values between 0.05 and 0.1 were considered as statistical trends.

RESULTS

Success

The logistic regression analysis for success of task 1 (?^{2} (1) = 0.88, $p = 0.35$) and task 3 (?^{2} (1) = 0.2, $p = 0.66$) indicated no effect of group. In contrast, the regression model for task 2 produced a statistically significant difference (?^{2} (1) = 4.43,$p < 0.05$) and explained 21.6% (Nagelkerke R^2) of the variance in success. Children in the DS group were 0.16 times less likely to succeed in task 2 compared to children in the TD group (Wald's ?^{2} = 3.84, $p = 0.05$). The percent success data for both the groups during each of the experimental tasks is provided in Figure 2.

Assistance

The multinomial regression model for tester assistance during task 1 was not significant ($?^2$ (2) = 1.27, p = 0.53). The model for task 2 ($?^2$ (2) = 8.62, p = 0.01) was statistically significant and explained 32.3% (Nagelkerke R^2) of the variance in tester assistance across groups. During task 2, it was 6.67 times more likely for children to seek partial assistance than no assistance if they were in the DS group compared to the TD group (Wald's $?^2$ = 3.04, p = 0.08). Similarly, it was 20 times more likely to seek total assistance than no assistance for children in the DS group compared to the TD group (Wald's $?^2$ = 5.61, $p < 0.05$). The model for task 3 ($?^2$ (2) = 9.24, p = 0.01) was also statistically significant and explained 33.9% (Nagelkerke R^2) of the variance in tester assistance across groups. During task 3, children were 21.33 times more likely to seek partial assistance than no assistance if they are in the DS group compared to TD group (Wald's $?^2$ = 5.92, p< 0.05). The percent data for tester assistance during the three tasks is provided in Figure 3.

Hand actions

The non-parametric Mann–Whitney U analysis for hand actions indicated similar performance across the two groups, except for the asymmetric bilateral actions during task 3 (U = 47; p = 0.05). To elaborate, children with DS showed less use of the relatively complex asymmetric hand movements during task 3 compared to children in the TD group (Table 2).

Planning and execution time

The non-parametric Mann–Whitney U analysis for time to plan indicated a statistical group trend for task 2 (U = 50; p= 0.08). Children in the DS group took more time to make their first manual contact with the toys during task 2 compared to TD children (Figure 4). There were no other group differences for time to plan for task 1 and task 3.

For the execution time, we first compared the percentage of children in the DS and TD group with 'execution time' data, and it was not different for task 1 (DS = 76.92%, TD = 100%, $?^2$ = 0.39,p = 0.53), task 2 (DS = 61.54%, TD = 92.31%, $?^2$ = 0.8, p = 0.37), and task 3 (DS = 69.23%, TD = 69.23%, $?^2$ = 0, p = 1). Execution data was not calculated for children who ended the task earlier (< 60 seconds) due to non-engagement or non-compliance. The non-parametric Mann–Whitney U analysis indicated a statistical group trend for the total execution time (U = 53; p = 0.1), such that children in the DS group (38.11 +- 8.1 seconds) took longer to complete the task compared to TD group (20.15 +- 2.27 seconds).

DISCUSSION

The current study used a series of object-retrieval tasks of increasing complexity and varying context to compare the performance of young children with DS with mental age-matched TD children. Overall, our results indicated that children with DS were more challenged by the tasks compared to the mental age-matched TD group. However, the results were highly task-specific highlighting a strong interaction with the level of task and contextual complexity. To elaborate, for the easier task 1 involving retrieving a toy from a transparent box, children with DS performed similarly to the TD group and did not differ in terms of overall success and hand use strategies. However, with increasing task and contextual complexity, children with DS demonstrated specific difficulties with overall success and performance during the task 2 and 3. For task 2, the DS group had less success, required greater adult assistance, and longer time to plan the actions compared to the TD group. For task 3, the DS group showed less use of asymmetric bimanual strategies and required greater tester assistance compared to the TD group. Lastly, the DS group took longer to execute the tasks compared to the TD group. Interestingly, both groups had similar success rate for task 3 which could be attributed to the floor effects of a complex object retrieval task involving both task and context complexity.

The motor impairments of children with DS and their impact on object retrieval was apparent during task 3. Specifically, children with DS showed limited use of asymmetric bimanual strategies during task 3 compared to the TD group, and no differences for the symmetric bimanual or unilateral hand use. Bimanual coordination is required for variety of daily tasks, and evidence from the typical population suggests later development of asymmetric compared to symmetric bimanual coordination (Brakke et al., 2007), and its dependence on both the individual and environmental factors (Kirschner & Tomasello, 2009; Pellegrini et al., 2004). Additionally, bimanual manipulation is an important achievement for refining consistent hand preference in children (Nelson, 2022). Children with DS have poor bilateral coordination compared to neurotypical children as assessed using standardized motor tests and motor tasks such as walking (Vali Noghondar et al., 2022; Nocera et al., 2021; Jobling, 1998). However, there is limited information on the development and origins of bimanual coordination in infants and young children with Down Syndrome. More importantly, principles guiding bimanual training has only been studied in adults with DS, such as bimanual coordination improves with visual information, stable handedness, and repeated practice in adults with DS (Ringenbach et al., 2012; Mulvey et al., 2011; Latash & Patterson, 2002). Future studies should examine the development of bimanual coordination in infants with DS along with the impact of individual (e.g., severity of motor, attentional deficits) and environmental factors (e.g., task difficulty, visual or auditory stimulus) on performance of infants.

Cognitive impairments, or more specifically differences in executive skills could also have impacted the overall success rate and task performance of children with DS. Global differences in executive skills or its subconstructs such as working memory, cognitive flexibility, and inhibitory control are commonly reported in children with DS (Tungate & Conners, 2021; Daunhauer et al., 2014). Similarly, for the study tasks, children were required to explore multiple strategies, inhibit certain predominant strategies (such as directly trying to grasp the toy without opening the lid), and choose the best strategy (such as asymmetric hand use involving stabilization with one hand and moving with the other hand). Clearly, children with DS were slower in planning, choosing, and executing the strategies compared to TD children, but these challenges became apparent only when the task was complex and/or had additional contextual complexity of reduced transparency level was added to the tasks.

The current study also indicated that children with DS required more time to plan and execute their actions compared to TD children. Slower movement initiation and execution have been commonly reported in individuals with DS (Charlton et al., 1996; de Campos et al., 2010; Kearney & Gentile, 2003; Latash et al., 2002). For example, young preschoolers with DS (Kearney & Gentile, 2003) as well as school-aged children with DS (Charlton et al., 1996) had slower speed of reaching and grasping movements compared to TD controls, along with greater difficulties in feedback-dependent motor control. However, slowing down could also be viewed as an adaptive strategy to improve movement accuracy and performance. Adults with DS were slower than typically developing adults while tapping a tablet with a stylus but had a similar accuracy rate of hitting the target (Lam et al., 2009). Furthermore, the trade-off between the speed of movement and accuracy was a function of task difficulty (i.e., size and distance). Similar research has not been done in children with DS, hence, it is unclear whether children with DS use slowing down as an adaptive strategy to improve task comprehension and/or performance. Slower processing and execution times could pose serious challenges on everyday functioning of children and have negative implications on the learning of new skills and behaviors. Therefore, we recommend future studies to further investigate slower initiation and slower movement rate in children with DS, as well as their implications on everyday functioning and acquisition of new skills.

Lastly, we would like to acknowledge the differences in family demographics in our study sample. Parental education years were significantly lower in the DS group compared to the TD group. Several studies examined the association of socioeconomic status (SES) such as parents' education and income with the child's development including cognitive and social-emotional development (Bradley & Corwyn, 2002). Specifically, low maternal/paternal education is associated with poor academic performance and lower IQ scores in their children, possibly due to lack of resources, stimulating environment, as well as differences in parenting styles and attitudes (Mercy & Steelman, 1982; Scarr & Weinberg, 1978). Research has also demonstrated less effective object exploration in infants residing in lower SES households compared to those living in higher-SES households (Tacke et al., 2015). However, if we follow the cut-offs for low and high SES in the above-mentioned studies, a majority of the DS families in our study sample could qualify for high SES. For example, Tacke et al. (2015) considered families with 2+ years of college education as high SES, and 11 out of the total 14 DS families in our sample had 12+ years of education and would thus fall under the high SES category (see Table 1 for average parent education years). We would recommend further investigation of family factors (e.g., parents' occupation, education) and neighborhood factors (e.g., geographic location) on child's exploration and manipulation of objects, especially focusing on intersectional factors that could exist for children with disabilities living in lower-SES households.

Limitations and Future Directions

Given the lack of studies on the ecological constraints of object retrieval skills in the DS population, we conducted a pilot study with a relatively small sample size. Future studies should attempt to replicate the results with larger sample sizes and longitudinal/cross-sectional comparison of this skill. Additionally, the current study included only a mental-age matched TD control, however, future studies should recruit children with other developmental disabilities to assess the sensitivity and specificity of means end delays in the DS population. Lastly, the current study did not assess the differential impact of task and contextual complexity on the means end exploratory behaviors of children with DS. For an in-depth investigation of this skill, future studies should include a variety of tasks with varying complexities/context.

CONCLUSION

The primary goal of the current study was to examine the role of ecological constraints (task and contextual complexity) on the object retrieval skills of young children with DS. The results indicated that children with DS perform poorly compared to mental-age matched TD children when contextual (retrieving toy from an opaque box) and task + contextual complexity (retrieving toy from a transparent box within an opaque box) is introduced. The poor performance of the DS population was related to poor bimanual hand use, poor executive skills, and slower processing/movement speeds. Given that object retrieval is a critical development skill, future studies are needed for an in-depth examination of the development and specificity of means-ends exploratory behaviors in children with DS. This will not only improve our understanding of the disorder but will also help clarify the treatment targets and goals for children with DS.

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