Voluntary Orienting Among Children and Adolescents With Down Syndrome and MA-Matched Typically Developing Children

Karen J. Goldman
David Yellin College of Education (Jerusalem)

Tara Flanagan
McGill University (Montréal)

Cory Shulman
Hebrew University of Jerusalem

James T. Enns
University of British Columbia

Jacob A. Burack
McGill University

Abstract
A forced-choice reaction-time (RT) task was used to examine voluntary visual orienting among children and adolescents with trisomy 21 Down syndrome and typically developing children matched at an MA of approximately 5.6 years, an age when the development of orienting abilities reaches optimal adult-like efficiency. Both groups displayed faster reaction times (RTs) when the target location was cued correctly than when cued incorrectly under both short and long SOA conditions, indicating intact orienting among children with Down syndrome. This finding is further evidence that the efficiency of many of the primary components of attention among persons with Down syndrome is consistent with their developmental level.

Empirical evidence of distinct behavioral and neurological profiles for specific syndromes (Burack, Hodapp, & Zigler, 1988; Dykens, Hodapp, & Finucane, 2000) is consistent with the conclusion that no single attentional impairment is common for all persons with mental retardation (Burack, Evans, Klaiman, & Iarocci, 2001; Iarocci & Burack, 1998), although one or more impairments may be associated with certain etiologies. Because attention is comprised of different components (Enns, 1990; Plude, Enns, & Brodeur, 1994), it can be affected uniquely by various types of organic damage (for a review, see Burack & Enns, 1997), primary areas of impaired or enhanced functioning need to be identified specifically for individual etiological groups (Burack et al., 2001; Iarocci & Burack, 1998). For example, the observations of difficulties shifting attention and searching in free-play situations among infants with Down syndrome (Krakow & Kopp, 1983; Landry & Chapieski, 1989) led to concerns about long-term general impairments in the orienting component of attention that involves the alignment of visual-processing resources in order to search for target objects (Wagner, Ganiban, & Cicchetti, 1990). In an initial experimental test of this hypothesis, Randolph and Burack (2000) failed to find differences in performance between persons with Down syndrome and typically developing children matched for mental age (MA) when searching for a target stimulus, regardless of the validity of a prior cue. However, the scope of this finding is limited because the focus was on covert orienting that involved nonvoluntary shifting of attention in relation to a peripheral physical change in the environment.

In this study, we extended Randolph and Burack's (2000) findings in two ways. First, we assessed voluntary or strategic rather than a reflexive shifting of attention by incorporating a centrally located informational cue (an arrow). Second, we included two stimulus onset asynchrony (SOA) conditions in order to examine the effects of duration between cue and target on performance.

Visual orienting entails shifting attention from one stimulus to another in relation to some information in the environment (Posner, 1980). It is often studied with reaction time (RT) tasks similar to one developed by Posner (1980), in which a cue is presented just prior to the appearance of a target stimulus. In this methodology both the length of the interval between the presentations of the cue and the target and the type of cue can be manipulated. At short intervals the entire cue-target sequence is presented in less time than is needed to initiate an eye movement to the cued location (i.e., eye movements to abrupt transient events in the visual parafovea usually take more than 250 msec). Yet, the mind's eye can be directed to a predicted location in less than that amount of time, thereby providing the opportunity to measure voluntary spatial orienting even under *covert* conditions (i.e., unaccompanied by spatially directed physical movements of the eye or head). At longer intervals, the physical eye may also be directed to the location that was already "visited" by the mind's eye of attention, although in simple orienting tasks, such as the one used here, the occurrence of such eye movements does not seem to affect the results (Enns, 1990; Plude et al., 1994).

A second factor that is varied in this procedure is the validity of the cue, such that the target's location is correctly indicated (valid trials) on a majority of trials and incorrectly indicated (invalid trials) on a smaller number of trials. Thus, the positively predictive nature of cue validity ensures that attention is oriented to the cued location. This typically results in enhanced performance for conditions with the valid cue but impeded performance for conditions with invalid cues because attention needs to be redirected from the incorrectly cued location to the target location.

The primary index of attention in this methodology is the *orienting effect*, which is derived by subtracting the RT on valid trials from the RT on invalid trials (e.g., Akhtar & Enns, 1989; Randolph & Burack, 2000). Shorter RTs on valid than invalid trials are evidence that processing was influenced by the location of the cue in relation to the target. This overall effect is also sometimes subdivided into benefits and costs of orienting, by using a neutral cue with no location-specific information that is as similar in form and presentation as possible to the location cues. Benefits are indexed by the difference between neutral RT and valid RT, whereas costs are indexed by the difference between invalid RT and neutral RT. However, the comparison of these separate component measures between two groups is premised on two assumptions that are difficult to defend. One is that the influence of the neutral cue is identical to the influence of the predictive cue, with the exception that it has no spatial biasing effect. This assumption is called into question by the finding that different types of neutral cues can yield a full range of performance between the extremes of valid and invalid conditions (Jonides & Mack, 1984). The second assumption is that the effects of the neutral cue on task performance are identical in both groups. This is problematic because the groups are known to differ on behavioral and neurological indices. Accordingly, we chose to examine performance differences between the two groups with the overall orienting effect, which controls for any a priori group differences in behavior and neurology, as all such differences are presumably reflected in both the invalid RT and valid RT that contribute to the orienting effect.

In order to examine voluntary visual orienting among children and adolescents with trisomy 21 Down syndrome as compared to MA-matched typically developing children, we developed a forced-choice RT task based on the location of the target stimulus with valid, invalid, and neutral cues and based on two SOA conditions (175 msec and 600 msec). The forced-choice aspect of the paradigm was designed to minimize false responses due to anticipatory responses. Responses were based on location rather than identity (e.g., Randolph & Burack, 2000) because this strategy is considered to be more ecologically valid and less biased by developmental differences (Tipper & McLaren, 1990). The cue validity was based on the direction of an arrow that either correctly or incorrectly predicted target location. In order to ensure the utility of the valid cue, the valid trials were presented approximately four times more often than the invalid trials. The average MA of both groups of participants was approximately 5.6 years, an age when the development of orienting abilities is nearing optimal adult-like levels of efficiency (Akhtar & Enns, 1989; Enns & Cameron, 1987) and, therefore, when the likelihood of identifying group differences is maximized.

Method

Participants

The participants were 12 children and adolescents (3 males, 9 females) diagnosed with trisomy 21 Down syndrome who were recruited from special schools in Jerusalem and 13 typically developing children (6 males, 7 females) who were recruited from public kindergartens. The mean chronological age (CA) of the participants with Down syndrome was 15 years (standard deviation [*SD*] = 2.93). Their mean nonverbal MA, based on the Leiter International Performance Scale (Leiter, 1940, 1979), was 5.6 years (*SD* = 0.64). The mean CA of the typically developing children was 5.6 years (*SD* = 0.45). All the typically developing children performed within one *SD* of the norm on the Matrices subtest of the Kaufman Brief Intelligence Test–KBIT (Kaufman & Kaufman, 1990), indicating that their nonverbal MA was commensurate with their CA.

The Leiter International Performance Scale (Leiter, 1979) was used to obtain a measure of cognitive functioning for the persons with Down syndrome because it is particularly appropriate for individuals with mental retardation (Levine, 1983). Levine reported a test–retest reliability of 0.91 and a construct validity of 0.78 with the Full-Scale IQ of the Wechsler Intelligence Scale for Children–Revised–WISC-R (Wechsler, 1974). The Matrices subtest of the Kaufman Brief Intelligence Test (Kaufman & Kaufman, 1990) is considered a good measure of general cognitive functioning with split-half and test–retest reliabilities of 0.85 and a construct validity of 0.56 with the Full-Scale IQ of the WISC (Kaufman & Kaufman, 1990).

Experimental Task

The task was presented on a laptop 586 processor computer with a 30.48 cm active matrix screen using specific programming to ensure accurate timing. Each trial started with a tone accompanying an asterisk that appeared at the fixation point in the middle of the screen. We varied the duration of the asterisk randomly between 1 and 1.5 seconds in order to prevent participants from anticipating the onset of the cue. At the offset of the asterisk, a cue appeared at the fixation point. The cue was either an arrow pointing right or left or a bar that served as a neutral cue. An arrow appeared in 168 of the 200 trials and the bar, in 32 of the trials. In 128 of the trials with the arrow, the direction of the arrow accurately predicted the location of the target stimulus that was to appear to the right or left of fixation. In 40 of the trials with an arrow, the direction of the arrow incorrectly predicted the location of the subsequent target. The direction of the arrow cue was equally often to the right or left. In the other trials, the bar served as a neutral cue. The interval between presentation of the cue and presentation of the target (the SOA) was 175 msec or 600 msec. The SOA was equally and randomly distributed within valid, invalid, and neutral conditions. Targets appeared equally often to the right and left of fixation at a distance of 6.3 cm (visual angle was 8 degrees). The target remained on the screen until the subject pressed a switch, or until 3 seconds elapsed. This sequence of events is illustrated in Figure 1.

Reaction time was measured in milliseconds and was the dependent measure in the statistical analyses. As is common practice in studies of young children or other persons who typically display high degrees of variability in their RTs, we used the median RT as the measure of central tendency (Burack, 1994).

Procedure

The participants were tested on three occasions within a one-week period. In the first session, the Leiter International Performance Scale was administered to the participants with Down syndrome and the Matrices subtest of the Kaufman Brief Intelligence Test, to the typically developing participants.

The second and third sessions were the experimental sessions. The participants were seated at a table with their eyes approximately 45 cm

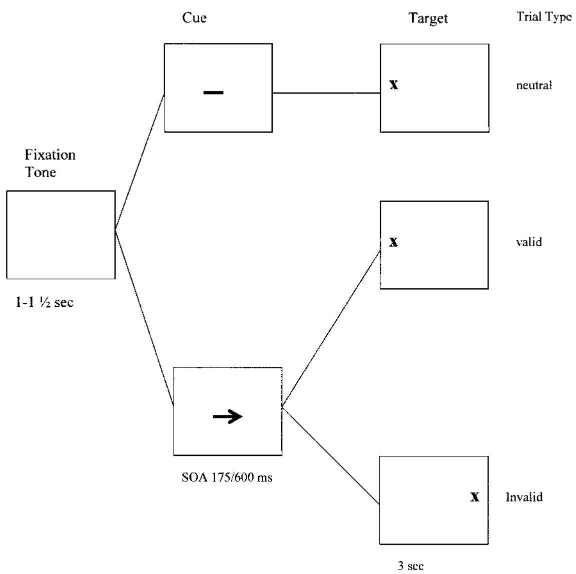

Figure 1. Sequence of events within individual trials. SOA = stimulus onset asynchrony.

from the computer screen. The response switches were placed in front of them, and they were told to place an index finger above each switch. The participants were told that they were going to play a game on the computer in which they had to find the *x*. They were told to press the switch on the same side as the target appeared as fast as possible, but only when they saw the *x*. They were told that at the end of the session, they would receive a small prize. During the initial 20 practice trials that began each session, the subjects were provided feedback about the accuracy of their responses, and instructions were repeated as necessary. A second set of practice trials was administered to a few of the subjects.

All sessions were conducted in a small, quiet room in the participant's school. During the testing session, the experimenter sat to the left of the participants and noted whether they were attending to the screen at the start of each trial. A total of 200 trials were administered over 2 sessions, with each session consisting of two sets of 50 trials separated by a break of a few minutes. Trials were deleted from the analyses if responses were incorrect, if they did not occur within 3 seconds, or if they occurred before the target appeared. Across both groups, we deleted 2.2% of the trials. Although the groups did not differ in the number of trials deleted, accuracy was significantly related to RT, $r = -.28$, $p < .01$, and incorrect responses were associated with slower RTs. This finding indicates that there was no speed–accuracy tradeoff.

Results

The dependent measure used in the analyses was the mean of the median correct RTs for each of the participants for each of the conditions. Reaction time scores by group for each condition are presented in Table 1.

General Analyses

A repeated measures ANOVA with group (children with Down syndrome and typically developing children) as the between-subject variable and SOA (175 msec, 600 msec) and cue (invalid, valid, neutral) as the within-subject repeated variables revealed main effects of group, $F(1, 23) = 11.69$, $p < .002$; SOA, $F(1, 23) = 79.45$, $p < .001$; and cue, $F(2, 22) = 11.62$, $p < .001$. The main effect of group reflected the generally shorter RTs of the participants with Down syndrome. The main effect of SOA reflected shorter RTs across both groups, with an SOA of 600 msec as compared to one of 175 msec. The main effect of cue reflected the facilitative role of the valid cue type. Post hoc comparisons revealed significant differences between the invalid and valid cue types, $F(1, 23) = 13.51$, $p < .001$, and between the valid and neutral cue types, $F(1, 23) = 18.47$, $p < .001$. In each case the valid cue type elicited shorter RTs. No interactions were found among any of the variables.

Table 1. Mean Reaction Times (in msec) by Group, Stimulus Onset Asynchrony (SOA), and Condition

Group/Condition	SOA 175 Mean	SOA 175 *SD*	SOA 600 Mean	SOA 600 *SD*
Down syndrome				
Invalid	753	177	649	110
Neutral	692	143	626	94
Valid	660	118	558	115
Typically developing				
Invalid	936	88	791	148
Neutral	923	171	789	151
Valid	846	204	724	190

The orienting effect was examined in a 2 (group) × 2 (SOA) repeated measures ANOVA in which the dependent repeated measure was the difference between the RTs on the invalid and valid trials for each SOA value. For the Down syndrome group, the mean for SOA 175 was 93 (*SD* = 142) and for the 600 msec SOA, 90 (*SD* = 107). For the typically developing group, the means were, respectively, 89 (*SD* = 142) and 67 (*SD* = 111). Neither main effects nor interactions were found.

An examination of the RTs for individual participants in the group of children and adolescents with Down syndrome revealed that 2 participants did not display an orienting effect (i.e., the invalid RT was not longer than the valid RT) at either SOA, and 1 participant failed to do so at the longer SOA. For the typically developing children, an inspection of the RTs for individual subjects indicated that 1 participant did not display an orienting effect (i.e., the invalid RT was not longer than the valid RT) at either SOA, 2 failed to do so at the shorter SOA, and 2 failed to do so at the longer SOA.

Discussion

The primary finding was that children and adolescents with trisomy 21 Down syndrome and typically developing children matched on visual–spatial MA of approximately 5.6 years showed generally similar patterns of cue effects on a voluntary visual-orienting task with both short- and long-SOA conditions. Both groups demonstrated enhanced performance with the valid as compared to the invalid cue and with an SOA of 600 msec as compared to one of 175 msec. Of course, this conclusion does not preclude the possibility of finding more subtle differences between these groups in future studies, especially those with larger sample sizes (for increased statistical power) and in which the factors of temporal course (cue-target SOAs) and cue predictability are examined in greater detail.

Evidence for the effect of cue validity among both the children with Down syndrome and the typically developing children for both the longer and shorter SOAs indicates similarities between the groups in orienting abilities in relation to information cues. These similarities between the groups indicate intact abilities to shift attention among children and adolescents with Down syndrome at a developmental level when transitions in developmental abilities are often apparent (Enns, 1990; Plude et al., 1994) and, therefore, when group differences might be expected (Burack et al., 2001; Burack, Iarocci, Bowler, & Mottron, 2002). The faster RTs with a longer SOA that were observed in both groups are also consistent with findings from studies with typically developing children and young adults (Brodeur & Enns, 1997; Enns & Richards, 1997).

Generally, the faster RTs of the children with Down syndrome are consistent with the commonly cited association between faster RTs and increasing CA in typically developing children that are likely due to physical maturity (e.g., Brodeur & Enns, 1997; Enns & Richards, 1997). The differences in CA of the two groups is obviously inherent to any comparison of persons with Down syndrome, or any other etiology associated with mental retardation, and typically developing children matched on a measure of MA (Burack et al., 2001). The finding of similarities in patterns of performance between the groups, despite differences in CA and RTs, therefore, highlights the strength of the relation between attentional processing and MA (Burack et al., 2001; Iarocci & Burack 1998).

Some evidence of group differences with regard to strategies or processes associated with the orienting effect was apparent in the pattern of RTs for each condition. Virtually the entire magnitude of the orienting effect displayed by the typically developing children appeared to be due to the benefits of the valid cue. In contrast, the magnitude of the orienting effect of the persons with Down syndrome seemed to arise from more of a combination of both the benefits of the valid cue and the costs of an invalid cue. This suggests possible differences between the groups in the use of strategies or processes, despite the similarities in the manifested levels of orienting behavior. These potential differences might be studied in the future with an experimental design that involves an independent assessment of the effects of neutral cues on these two populations by including a range of different neutral cue types that vary in their effects on general alertness and in their tendency to bias participants' attention away from the various target locations (Jonides & Mack, 1984).

In summary, the main finding in this study adds to the growing list of similarities in the efficiency of attentional processes between persons with Down syndrome and typically developing children, when level of development is properly measured and taken into account (Iarocci & Burack, 1998; Randolph & Burack, 2000; Wagner et al., 1990).

References

Akhtar, N., & Enns, J. T. (1989). Relations between covert orienting and filtering in the development of visual attention. *Journal of Experimental Child Psychology, 48,* 315–334.

Brodeur, D. A., & Enns, J. T. (1997). Lifespan differences in covert visual orienting. *Canadian Journal of Experimental Psychology, 51,* 20–35.

Burack, J. A. (1994). Selective attention deficits in persons with autism: Preliminary evidence of an inefficient attentional lens. *Journal of Abnormal Psychology, 103,* 535–543.

Burack, J. A., & Enns, J. T. (Eds.). (1997). *Attention, development, and psychopathology.* New York: Guilford Press.

Burack, J. A., Evans, D. W., Klaiman, C., & Iarocci, G. (2001). The mysterious myth of attentional deficit and other defect stories: Contemporary issues in the developmental approach to mental retardation. *International Review of Research in Mental Retardation, 24,* 300–321.

Burack, J. A., Hodapp, R. M., & Zigler, E. (1988). Issues in the classification of mental retardation: Differentiating among organic etiologies. *Journal of Child Psychology and Psychiatry, 29,* 765–779.

Burack, J. A., Iarocci, G., Bowler, D. M., & Mottron, L. (2002). Benefits and pitfalls in the merging of disciplines: The example of developmental psychopathology and the study of persons with autism. *Development and Psychopathology, 14,* 225–237.

Dykens, E. M., Hodapp, R. M., & Finucane, B. M. (2000). *Genetics and mental retardation syndromes.* Baltimore: Brookes.

Enns, J. T. (1990). Relations between components of visual attention. In J. T. Enns (Ed.), *The development of attention: Research and theory.* Amsterdam: Elsevier Science.

Enns, J. T., & Cameron, S. (1987). Selective attention in young children: The relations between visual search, filtering, and priming. *Journal of Experimental Child Psychology, 44,* 38–63.

Enns, J. T., & Richards, J. C. (1997). Visual attentional orienting in developing hockey players. *Journal of Experimental Child Psychology, 64,* 255–275.

Iarocci, G., & Burack, J. A. (1998). Understanding the development of attention in persons with mental retardation: Challenging the myths. In J. A. Burack, R. M. Hodapp, & E. Zigler (Eds.), *Handbook of mental retardation and development* (pp. 349–381). New York: Cambridge University Press.

Jonides, J., & Mack, R. (1984). On the cost and benefit of cost and benefit. *Psychological Bulletin, 96,* 29–44.

Kaufman, A., & Kaufman, N. L. (1990). *Kaufman Brief Intelligence Test.* Circle Pines, MN: American Guidance Service.

Krakow, J. B., & Kopp, C. (1983). The effects of developmental delay on sustained attention in young children. *Child Development, 54,* 1143–1155.

Landry, S. H., & Chapieski, M. L. (1989). Joint attention and infant toy exploration: Effects of Down syndrome and prematurity. *Child Development, 60,* 103–118.

Leiter, R. G. (1940). *The Leiter International Performance Scale.* Santa Barbara, CA: Santa Barbara College Press.

Leiter, R. G. (1979). *The Leiter International Performance Scale.* Chicago: Stoelting.

Levine, M. N. (1983). *Leiter International Performance Scale: A handbook.* Chicago: Western Psychological Services.

Plude, D. J., Enns, J. T., & Brodeur, D. A. (1994). The development of selective attention: A life-span overview. *Acta Psychologica, 86,* 227–272.

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology, 32,* 3–25.

Randolph, B., & Burack, J. A. (2000). Visual filtering and covert orienting in persons with Down syndrome. *International Journal of Behavioral Development, 24,* 167–172.

Tipper, S. P., & McLaren, J. (1990). Evidence for efficient visual selectivity in children. In J. T. Enns (Ed.), *The development of attention: Research and theory.* Amsterdam: Elsevier Science.

Wagner, S., Ganiban, J. M., & Cicchetti, D. (1990). Attention, memory, and perception in infants with Down syndrome: A review and commentary. In D. Cicchetti & M. Beeghly (Eds.), *Children with Down syndrome: A devel-*

opmental perspective. New York: Cambridge University Press.
Wechsler, D. (1974). *Wechsler Intelligence Scale for Children-Revised.* New York: Psychological Corp.

Editor-in-charge: *Frances Conners*

This project was supported by research grants from the Social Sciences and Humanities Research Council of Canada and the Hebrew University of Jerusalem to Jake Burack and by the Natural Sciences and Research Council of Canada to Jim Enns. The final author is also affiliated with Hôpital Rivière-des-Prairies, Québec. The authors thank Yaffa Goldberg and Aryeh Supperstein for their assistance with the computer programming, and Beth Randolph for her help with the development of the task and ideas. Requests for reprints should be sent to Jake Burack, Department of Educational and Counselling Psychology, 3700 McTavish St., Montréal, Quebéc, Canada, H3A 1Y2. E-mail: jake.burack@.mcgill.ca

