Preattentive Orienting in Adolescents With Mental Retardation

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Abstract

Visual attention is preattentively drawn to abrupt onsets of stimuli appearing in a visual array. In this experiment, I examined the speed of attentional capture for persons with and without mental retardation. Participants identified target stimuli that were signaled by a valid location cue (20% of the time), an invalid location cue (60% of the time), or no cue (20% of the time). Participants without mental retardation exhibited maximum influence of the cue at cue/target separations that were 100 msec shorter than did participants with mental retardation. These results indicate that processing-speed differences between persons with and those without mental retardation can be observed even when processing resources not involved in the information processing.

Visual information processing is generally characterized as involving two separate modes of processing (e.g., Broadbent, 1977; Neisser, 1967; Theeuwes, 1991, 1994; Triesman & Gelade, 1980). One mode, typically referred to as preattentive processing, is viewed as an unlimited capacity system that is capable of processing stimuli at multiple locations in parallel. Traditionally, *preattentive processes* are assumed to support relatively low level visual information-processing such as feature detection (Treisman, Voera, & Hayes, 1992). The second mode, referred to as *attentive processing,* requires the allocation of attentional resources to a particular area of space to be performed. As a result, attentive processes are limited in capacity and must operate in serial fashion (e.g., Triesman & Gelade, 1980). However, attentive processes have the advantage of permitting a more detailed analysis and synthesis of the visual information.

The cognitive systems that support preattentive and attentive visual processing develop very early in life and can be distinguished from each other by the time a normally developing child is 6 months old. Preattentive processing, which is thought to be governed by processes that are innate or fully developed very early in life, has been empirically demonstrated in infants as young as 3 and 4 months (Colombo, Ryther, Frick, & Gifford, 1995). Colombo et al. examined visual fixation times of infants during a feature search task and observed a "pop out" effect (Triesman & Gelade, 1980) indicative of feature detection through preattentive search processes. Attentive processing, which is known to develop over an extended developmental period, is clearly evidenced in 2- and 3-month-old infants with the development of the ability to disengage attention from highly salient stimuli to which young infants appear to be preattentively drawn (e.g., Atkinson, Hood, Wattam-Bell, & Braddick, 1992; Hood & Atkinson, 1993). Despite the early appearance of attentive processing, it is generally acknowledged that the ability to use attentive processes to shift visual focus continues to develop into adolescence (see Atkinson & Hood, 1997).

Researchers conducting studies with adolescents and young adults with mental retardation have often found that performance differences between them and persons without mental retardation matched on chronological age (CA) are typically associated with attention demanding aspects of cognitive tasks rather than those that occur preattentively or automatically (e.g., Atwell, Conners, & Merrill, 2003; Carlesimo, Marotta, & Vicari, 1997; Cody & Borkowski, 1977; Ellis, Katz, & Williams, 1987; Sperber & McCauley, 1984; Wyatt & Conners, 1998). In fact, important aspects of performance differences between persons with and without mental retardation are often minimized when tasks are structured to allow stimuli to preattentively guide the performance of persons with mental retardation (e.g., Carlin, Soraci, Goldman, & McIlvane, 1995; Carlin et al., 2002). For example, Carlin et al. (1995) demonstrated that preattentive processes were sufficient to perform a visual feature search for color and orientation but not for shape and size for persons with mental retardation. When preattentive processes were sufficient to perform the search, the participants with mental retardation exhibited a flat slope that was similar to that typically exhibited by persons without mental retardation during visual feature search. However, when preattentive processes were not sufficient, the performance of the participants with mental retardation suffered.

Although performance differences between persons with and without mental retardation are often smaller or nonexistent when preattentive rather than attentive processes are compared, there is a small body of literature suggesting that differences in preattentive processing may also be found (e.g., Fox & Oross, 1988; Lally & Nettelbeck, 1977; Merrill et al., 1987; Nettelbeck & Lally, 1979). For example, Fox and Oross (1988) examined stereoscopic depth perception of adults with mild mental retardation and concluded that persons with and without mental retardation exhibited deficiencies associated with preattentive perceptual processing that limited their ability process depth information presented in random-element stereograms. In addition, Merrill et al. (1987) reported a 100-msec difference between persons with and without mental retardation in the time required to encode pictures for the purpose of matching on the basis of physical identity. The physical identity encoding task appears to tap into the relatively automatic/preattentive encoding of physical features of a stimulus in that differences between groups are not influenced by secondary task demands (e.g., Merrill & Peacock, 1994). Nettelbeck and Lally (1979) reported a similar 100-msec difference between persons with and without mental retardation in the time needed to register sensory information to decide which of two lines was longer (i.e., inspection time). Importantly, these last two results were true for persons with and without mental retardation who were matched on mental age (MA) as well as CA, suggesting that the difference was not necessarily due to differences in cognitive developmental levels.

My purpose in conducting this study was to assess possible differences in preattentive processing of individuals with and without mental retardation. I used an involuntary orienting task in which covert attention is captured by the abrupt onset of a single stimulus (e.g., Folk, Remington, & Johnston, 1992; Remington, Johnston, & Yantis, 1992). In the task, a target stimulus can appear in one of several locations. The abrupt onset is a flashing stimulus that can appear in one of the possible locations of the target on a few trials. When the flashing stimulus does occur, it usually indicates a position in which the target will not appear to prevent participants from overtly using the stimulus as a cue for the location of the target. In addition, participants are told that they should ignore the flashing stimulus because it does not show where the target will appear. Hence, it is assumed that when the flashing stimulus influences a participant's performance, it is involuntarily. On a small percentage of the trials when the flashing stimulus is presented, the flashing stimulus does signal the location of the target. The involuntary capture of attention is indexed by increases in response times to identify the target when the flashing stimulus signals a location different from the target and decreases in response times when the flashing stimulus signals a location the same as the target (relative to when no flashing stimulus is presented). Theeuwes (1995; Theeuwes, Kramer, Hahn, & Irwin, 1998) reported that salient abrupt onsets capture attention of adults without mental retardation irrespective of the attentional set of the observer and that even when a known target is presented simultaneously, the salient abrupt onset captures attention. Hence, the ability to inhibit attentional capture seems very limited, if possible at all.

A qualitative difference between groups in the likelihood of exhibiting attentional capture was not expected; that is, I expected that the flashing stimulus would draw the attention of persons with mental retardation as has been shown for persons without mental retardation. Rather, I predicted that there would be a difference in the speed with which attention was pulled from one spatial location and shifted to the location of the flashing stimulus. Therefore, the primary manipulation to assess group differences was the time between the onset of the flashing stimulus and the onset of the target stimulus. In the present experiment, the flashing cue–target stimulus onset asynchrony (SOA) systematically varied from 0 to 400 msec. The amount of time needed to complete the involuntary attentional shift is reflected in the SOA at which minimum response times are first observed when the cue accurately predicts the location of the target and maximum response times are first observed when the cue inaccurately predicts the location of the target (e.g., Folk et al., 1992).

Method

Participants

Participants were 20 adolescents with mental retardation, 20 adolescents without mental retardation, and 20 children without mental retardation. The participants with mental retardation had a mean CA of 17.5 years (standard deviation [*SD*] = .7), a mean IQ of 58.4 (*SD* = 5.9), and a mean estimated MA of 9.3 (*SD* = 1.1). Their IQs were obtained from school records and based on recent administrations of the Wechsler Intelligence Scale for Children—WISC (within 2 years). I estimated MA using the formula MA = CA × IQ/100, with 16 as the upper limit for CA. None of the participants with mental retardation were known to have nor exhibited physical characteristics that indicated Down or fragile X syndromes.

The adolescents without mental retardation were selected to approximately match the adolescents with mental retardation on CA (*M* = 17.9, *SD* = .5). The children without mental retardation had a mean CA of 8.4 and were selected to be a conservative match for the adolescents with mental retardation on MA. Their MA was assumed to be roughly equivalent to their CA.

The adolescents without mental retardation were selected from introductory psychology classes at the University of Alabama and received course credit for their participation. The participants with mental retardation and the children without mental retardation were recruited from local schools and received a $5.00 gift certificate for participating. None of the sample members were on medication at time of testing.

Apparatus and Stimuli

Stimuli were presented using the Superlab experimental software program (Cedrus Corp.) on a

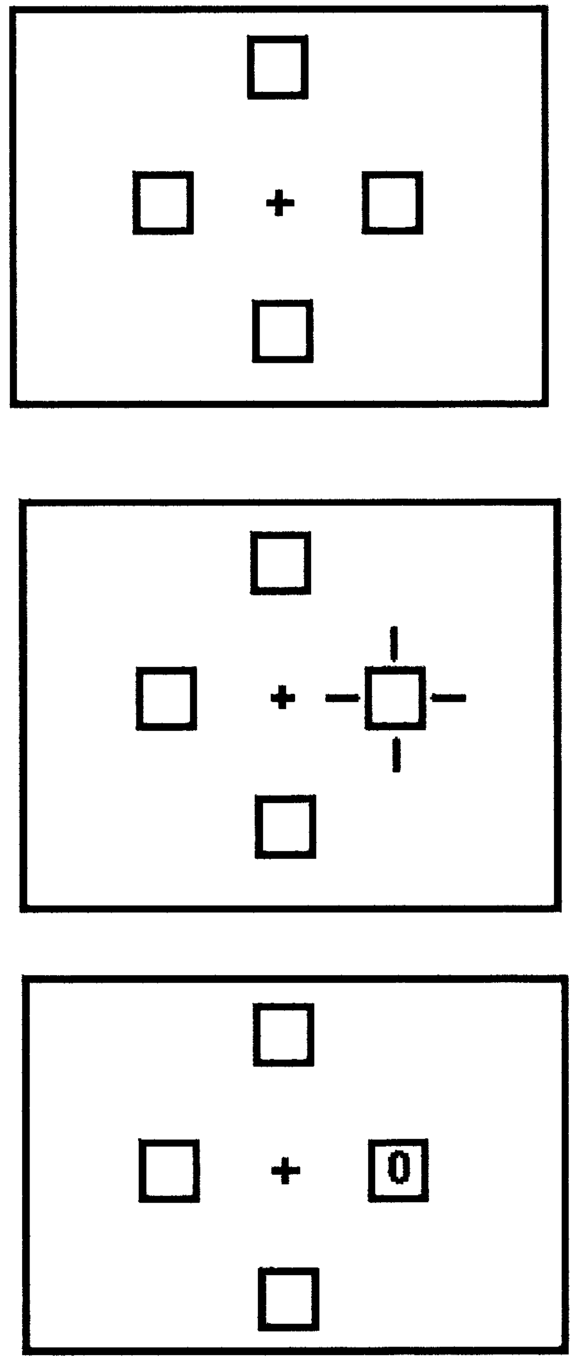

Figure 1. Sequence of events across stimulus displays on each trial. Figure 1 depicts a valid cue trial.

Macintosh LC computer. Examples of the stimuli are presented in Figure 1. Each stimulus display consisted of a central fixation cross and four empty squares at 12, 3, 6, and 9 o'clock. These were presented at the start of each trial and remained on the screen throughout the trial. The flashing stimulus, or cue, was a set of four bars that surrounded, but did not touch, one of the squares on trials when a cue was presented. The possible targets were the numbers 0 and 8 presented in bold lines in one of the squares. With participants seated 50 cm from the display, the entire display fit within 3-degrees visual angle from central fixation in all directions. Each square subtended approximately .6-degrees visual angle, and the targets subtended approximately .3 degrees visual angle.

The sequence of events was as follows on each trial. The screen depicting the four squares and the fixation cross was presented. The cue appeared 750 msec later and flashed around one of the squares (if a cue was to be presented), followed at the designated SOA by a target presented in one of the squares. The cue was visible for 100 msec. The target screen was visible until a response was made. The participants' response cleared the screen for 1 second. The next trial was presented immediately thereafter. Cues appeared on 80% of the total of 100 trials at each of four SOA presentations. Cues accurately predicted the location of the cue on 20% of the trials (valid cue) and inaccurately depicted the location of the target on the other 60% of the trials (invalid cue) that a cue was presented.

Design and Procedure

The variables in the experiment were group (mentally retarded, CA, and MA), cue type (none, valid, and invalid), and SOA (0, 200, 300, and 400 msec). Cue type and SOA were manipulated within participants; SOA was presented in separate blocks, with the presentation order counterbalanced such that each SOA was presented first, second, third, or fourth an equal number of times for each group. The dependent variable was target identification times. Response times and errors were recorded automatically by the computer.

Each participant was tested individually. They were seated approximately 50 cm from the computer screen and told that a 0 or 8 would appear in one of the squares on the screen on each trial and that their primary goal was to identify the target as rapidly as possible. Responses were made manually, with participants pressing the left response key for 0 and the right key for 8. They were told about the flashing stimulus and informed that they should ignore the flashes because they would not help them locate the target on most trials. Participants received 10 practice trials to ensure they understood the procedure, followed by the experimental trials. A 2- to 5-minute break was provided halfway through the experiment. The entire session lasted approximately 30 minutes.

Results

Mean target identification times are reported in Table 1. Error rates were low and, following arc-sin transformation of error data, did not vary significantly with groups or conditions. The data used in the primary analysis were the facilitation scores (valid–no cue) and interference scores (invalid–no cue) calculated for each participant to eliminate the influence of overall reaction time differences on the analysis. These data are also presented in Table 1. The analysis was a 3 (group) $\times$ 2 (validity condition) $\times$ 4 (SOA) analysis of variance, with validity condition and SOA treated as within-subjects variables.

The analysis revealed a significant main effect of validity condition, $F(1, 57) = 46.64$, $p < .01$, with participants exhibiting the expected facilitation in the valid condition and interference in the invalid condition. There was also a significant main effect of SOA, $F(3, 171) = 4.54$, $p < .01$. However, these effects were qualified by the significant two-way interaction of Validity Condition $\times$ SOA, $F(3, 171) = 22.92$, $p < .01$, and the significant three-way interaction of Group $\times$ Validity Condition $\times$ SOA, $F(6, 171) = 4.40$, $p < .01$. The three-way interaction was examined by evaluating the effects of validity condition and SOA separately for each group. For the participants with mental retardation, the analysis revealed a significant Validity Condition $\times$ SOA interaction, $F(3, 57) = 11.41$, $p < .01$. Tests of simple effects indicated a significant effect of SOA for both the valid cue condition, $F(3, 57) = 2.87$, $p < .05$, and invalid cue condition, $F(3, 57) = 8.78$, $p < .01$. A comparison of means using Tukey's HSD indicated that facilitation increased between the 0 msec and 300 msec SOA in the valid cue condition and that interference increased between the 0 msec and 300 msec SOA in the invalid cue condition and remained the same thereafter, all significant *p*s $< .05$. For the matched-CA participants, the analysis revealed a significant Validity Condition $\times$ SOA interaction, $F(3, 57) = 10.62$, $p < .01$. Tests of simple effects indicated a significant effect of SOA for both the valid cue condition, $F(3, 57) = 12.38$, $p < .01$, and invalid

Table 1. Mean Response Times as a Function of Group, SOA, and Cue Validity

	Stimulus onset asynchrony											
	0			200			300			400		
Group/Cue validity	RT[a]	*SD*	E%[b]	RT	*SD*	E%	RT	SD	E%	RT	SD	E%
Mentally retarded												
Valid	327	75.2	2.2	315	70.4	3.3	293	65.0	2.5	277	62.9	1.8
Invalid	324	65.7	2.1	323	73.3	2.4	374	79.2	2.5	347	74.6	2.2
No cue	326	72.5	2.4	320	60.8	2.1	335	75.4	2.3	300	69.2	2.0
Facilitation effects	1			−5			−42			−23		
Interference effects	−2			3			39			47		
Equal CA												
Valid	204	44.2	0.6	155	40.9	1.0	146	45.8	1.2	178	42.3	1.2
Invalid	207	42.5	1.2	230	51.7	1.1	233	43.5	0.9	206	45.1	1.3
No cue	205	41.6	0.7	197	45.3	1.6	194	47.1	1.0	177	42.5	0.8
Facilitation effects	−1			−42			−48			1		
Interference effects	2			33			39			29		
Equal MA												
Valid	269	54.3	1.4	216	50.2	2.3	210	45.1	1.7	247	52.9	1.8
Invalid	272	55.7	1.0	297	60.1	1.4	288	59.8	2.7	275	52.7	1.1
No cue	269	56.6	2.2	257	50.8	2.0	244	48.4	1.3	251	52.3	1.2
Facilitation effects	0			−41			−34			−4		
Interference effects	3			40			44			44		

Note. Mean facilitation effects = valid–no cue and mean interference effects = invalid–no cue.
[a] Reaction time. [b] Error percentage.

cue condition, $F(3, 57) = 2.86$, $p < .05$. A comparison of means using Tukey's HSD indicated that facilitation increased between the 0-msec and 200-msec SOA in the valid cue condition and that interference increased between the 0-msec and 200-msec SOA in the invalid cue condition, with no additional increase after the 200-msec SOA, all significant *p*s $< .05$. For the matched-MA participants, the analysis revealed a significant Validity Condition × SOA interaction, $F(3, 57) = 9.91$, $p < .01$. Tests of simple effects indicated a significant effect of SOA for both the valid cue condition, $F(3, 57) = 12.38$, $p < .01$, and invalid cue condition, $F(3, 57) = 2.86$, $p < .05$. A comparison of means using Tukey's HSD indicated that facilitation increased between the 0-msec and 200-msec SOA in the valid cue condition and interference increased between the 0-msec and 200-msec SOA in the invalid cue condition, with no additional increase after the 200-msec SOA (all significant *p*s $< .05$). The two groups without mental retardation also exhibited a significant decrease in facilitation in the valid cue condition when the SOA was 400 msec, possibly indicating that attention was returning to center fixation after being drawn to the location of the cue.

Discussion

Several features of the results are relevant to the comparison of preattentive orienting of persons with and without mental retardation. First, when the cue was valid, all groups exhibited faster response times to identify the target relative to the no cue condition as SOA increased from 0 msec. This pattern of performance indicates that attention was drawn to the location of the target and facilitated identification of the target when the cue was valid. Second, when the cue was not valid, all groups exhibited slower response times to identify the target relative to the no cue condition as SOA increased from 0 msec. Hence, attention appears to have been drawn to the cue even though it was not valid and interfered with response times when the target appeared in alternative locations. Because the cue was only valid on 20% of the trials (25% of the time a cue was presented) and participants were instructed to ignore the flashing stimulus, it is likely that they were not actively using the cue but, rather, were drawn to the cue preattentively and could not ignore it under the present conditions. Further, there was no evidence of any qualitative difference in performance associated with the age and IQ differences evaluated in this study. All groups were drawn to the flashing stimulus and it influenced target identification performance in a similar manner.

Although all groups were influenced in the same way by the flashing stimulus, it appears that the temporal characteristics of preattentive orienting differed for the groups. More specifically, the data indicated that both the CA and the MA participants reached maximum facilitation in the valid condition and maximum interference in the invalid condition by 200 msec. The participants with mental retardation did not exhibit maximum facilitation and interference until 300 msec had passed. The observation of processing time differences between persons with and without mental retardation is not new (see Kail, 1992; Sperber & McCauley, 1984). For example, Kail reviewed 45 studies in which persons with mental retardation performed more slowly on speeded tasks than did persons without mental retardation and concluded that some global mechanism of information processing, such as limited processing resources, was responsible for group differences on speeded tasks. It is less likely that the concept of limited processing resources applies to the group differences in processing speed observed in this study.

Visual capture of attention, as measured in this study, is typically involuntary and overrides attention being directed elsewhere (Theeuwes, 1995; Theeuwes et al., 1998). The process captures attention but is not under the influence of attention. Hence, this research is more consistent with the relatively small body of literature that indicates a possible quantitative difference in the execution of fundamental cognitive processes that do not use cognitive processing resources to be executed, such as stimulus encoding (Merrill et al., 1987) and inspection time (Nettelbeck & Brewer, 1981). These data raise the possibility that processing-speed differences between groups of individuals may be mediated by more than one cognitive mechanism. Such a suggestion is consistent with recent data obtained in the comparison of cognitive processing efficiency between younger and older adults without mental retardation (e.g., Verhaeghen et al., 2002). The nature of the possible different mechanism involved in accounting for speed of processing differences has not been determined, and my data do not address this issue.

It is also important to consider possible limitations of the results obtained in this experiment. The most obvious limitation is based on the fact that preattentive processing is stimulus driven. As has been demonstrated by Carlin and colleagues (e.g., Carlin et al., 1995, 2002), the speeded performance of persons with mental retardation is often affected by the experimenter's choice of stimuli. I chose the flashing stimulus presentation because it has consistently led to attentional capture for young adults without mental retardation (e.g., Folk et al., 1992; Theeuses, 1991, 1994). It may be that increasing the intensity of the stimulus presentation used in this experiment or some other stimulus presentation may attract attention more readily for the persons with mental retardation than occurred here and, thereby, reduce the magnitude of the difference between groups.

The second clear limitation concerns the lack of specificity of the basic result. For example, the choice of SOAs did not allow any greater precision in estimating processing-speed differences among groups. If I had included a 100-msec interval, I may have observed a difference between the two groups of participants without mental retardation, and if I included intervals between 200 and 300 msec, it is possible that the magnitude of the difference among groups may have been smaller. Neither was possible for practical reasons.

A third limitation is that these data did not permit me to distinguish between time differences resulting from a slow initiation of the shift of attention versus a slower movement of attention from one location to another, or some combination of both. Nevertheless, the basic result is important because it does indicate that a simple cognitive resource account of processing-speed differences between persons with and without mental retardation is not sufficient.

References

Atkinson, J., & Hood, B. (1997). Development of visual attention: Bridging disciplines. In J. A. Burack & J. T. Enns (Eds.), *Attention, development, and psychopathology* (pp. 31–54). New York: Academic Press.

Atkinson, J., Hood, B., Wattam-Bell, J., & Braddick, O. (1992). Changes in infants' ability to switch visual attention in the first three months of life. *Perception, 21,* 643–653.

Atwell, J. A., Conners, F. A., & Merrill, E. C. (2003). Implicit and explicit learning in young adults with mental retardation. *American Journal on Mental Retardation, 108,* 56–68.

Broadbent, D. E. (1977). The hidden preattentive processes. *American Psychologist, 32,* 109–118.

Carlesimo, G. A., Marotta, L., & Vicari, S. (1997). Longterm memory in mental retardation: Evidence for a specific impairment in subjects with Down's syndrome. *Neuropsychologia, 35,* 71–79.

Carlin, M. T., Soraci, S. A., Goldman, A. L., & McIlvane, W. (1995). Visual search in unidimensional arrays: A comparison of individuals with and without mental retardation. *Intelligence, 21,* 175–195.

Carlin, M. T., Soraci, S. A., Dennis, N. A., Strawbridge, C., & Chechile, N. A. (2002). Guided visual search in individuals with mental retardation. *American Journal on Mental Retardation, 107,* 237–251.

Cody, W. J., & Borkowski, J. G. (1977). Proactive interference and its release in short-term memory of mildly retarded adolescents. *American Journal of Mental Deficiency, 82,* 305–308.

Colombo, J., Ryther, J. S., Frick, J. E., & Gifford, J. J. (1995). Visual pop-out in infants: Evidence for preattentive search in 3- and 4-month olds. *Psychonomic Bulletin and Review, 2,* 266–268.

Ellis, N. R., Katz, E., & Williams, J. E. (1987). Developmental aspects of memory for spatial location. *Journal of Experimental Child Psychology, 44,* 401–412.

Folk, C. L., Remington, R., & Johnston, J. C. (1992). Involuntary covert orienting is contingent on attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance, 18,* 1030–1044.

Fox, R., & Oross, S. (1988). Deficits in stereoscopic depth perception by mildly mentally retarded adults. *American Journal on Mental Retardation, 93,* 232–244.

Hood, B. M., & Atkinson, J. (1993). Disengaging visual attention in the infant and adult. *Infant Behavior and Development, 16,* 405–422.

Kail, R. (1992). General slowing of information-processing by persons with mental retardation. *American Journal on Mental Retardation, 97,* 333–341.

Lally, M., & Nettelbeck, T. (1977). Intelligence, reaction time, and inspection time. *American Journal of Mental Deficiency, 82,* 273–282.

Merrill, E. C., & Peacock, M. (1994). Allocation of attention and task difficulty. *American Journal on Mental Retardation, 98,* 588–593

Merrill, E. C., Sperber, R. D., McCauley, C., Littlefield, J., Rider, E. A., & Shapiro, D. (1987). Picture encoding speed and mental retardation. *Intelligence, 11,* 169–191.

Neisser, U. (1967). *Cognitive psychology*. New York: Appleton-Century–Crofts.

Nettelbeck, T., & Brewer, N. (1981). Studies of mild mental retardation and timed performance. In N. R. Ellis (Ed.), *International review of research in mental retardation* (Vol. 10, pp. 61–106). New York: Academic Press.

Nettelbeck, T., & Lally, M. (1979). Age, intelligence, and inspection time. *American Journal of Mental Deficiency, 83,* 398–401.

Remington, R. W., Johnston, J. C., & Yantis, S. (1992). Involuntary attentional capture by abrupt onsets. *Journal of Experimental Psychology: Human Perception and Performance, 18,* 279–290.

Sperber, R. D., & McCauley, C. (1984). Semantic processing efficiency in the mentally retarded. In P. Brooks, R. Sperber, & C. McCauley (Eds.), *Learning and cognition in the mentally retarded* (pp. 141–163). Hillsdale, NJ: Erlbaum.

Theeuwes, J. (1991). Exogenous and endogenous control of attention: The effect of visual onsets and offsets. *Perception and Psychophysics, 50,* 184–193.

Theeuwes, J. (1994). Endogenous and exogenous control of visual selection. *Perception, 23,* 429–440.

Theeuwes, J. (1995). Abrupt luminance change pops out; Abrupt color change does not. *Perception and Psychophysics, 57,* 67–74.

Theeuwes, J., Kramer, A. F., Hahn, S., & Irwin, D. E. (1998). Our eyes do not always go where we want them to go: Capture of the eyes by new objects. *Psychological Science, 9,* 379–385.

Triesman, A. M., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology, 12,* 97–136.

Treisman, A., Vieira, A., & Hayes, A. (1992). Automaticity and preattentive processing. *American Journal of Psychology, 105,* 341–362.

Verhaeghan, P., Cerella, J., Semenec, S. C., Leo, M. A., Bopp, K. L., & Steitz, D. W. (2002). Cognitive efficiency modes in old age: Performance on sequential and coordinative verbal and visuospatial tasks. *Psychology and Aging, 17,* 558–570.

Wyatt, B. S., & Conners, F. A. (1998). Implicit and explicit memory in individuals with mental retardation. *American Journal on Mental Retardation, 102,* 511–526.

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