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Revisiting Inhibitory Control Across the Life Span: Insights From the Ex-Gaussian Distribution

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Changes in inhibitory control occur across the life span and have been associated with alterations in prefrontal function. In this study, ex-Gaussian analysis was used to reexamine data from an inhibitory control task. Participants (ages 6 to 82 years) composed three groups: children, young adults, and older adults. In fitting the ex-Gaussian distribution to reaction time data, estimates of three parameters were obtained: mu (μ), reflecting average performance; sigma (σ), reflecting variability in performance; and tau (τ), reflecting extremes in performance. Older adults differed from young adults in terms of mu, sigma, and tau. For children, mu and tau values were comparable to those of young adults; sigma, however, was different. Thus, inhibitory changes in older adults were due to slower, more variable, and more extreme responding. Inhibitory changes in children were due only to more variable responding. These findings suggest that different mechanisms underlie age-related changes in inhibitory control during different epochs of the life span. This study demonstrates that the ex-Gaussian approach provides a finer level of analysis than data analytic approaches typically used in neuropsychological research.

Age-related changes in inhibitory control occur across the life span. Specifically, inhibitory control improves during childhood (Carver, Livesey, & Charles, 2001; Diamond & Taylor, 1996; Gerstadt, Hong, & Diamond, 1994; Livesey & Morgan, 1991; Wright, Waterman, Prescott, & Murdoch-Eaton, 2003) and declines during late adulthood (Christ, White, Mandernach, & Keys, 2001; Girelli, Sandrini, Cappa, &

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Butterworth, 2001; Kramer, Humphrey, Larish, Logan, & Strayer, 1994; Spieler, Balota, & Faust, 1996; Van der Lubbe & Verleger, 2002; Williams, Ponesse, Schachar, Logan, & Tannock, 1999). These life-span changes have been related to concomitant alterations in the structure and function of the prefrontal cortex (for an overview, see Krasnegor, Lyon, & Goldman-Rakic, 1997), a brain region that plays a crucial role in inhibitory control (e.g., Durston et al., 2002; Hazletine, Poldrack, & Gabrieli, 2000; Konishi et al., 1999; Leung, Skudlarski, Gatenby, Peterson, & Gore, 2000; Liddle, Kiehl, & Smith, 2001; Rubia et al., 2001).

A variety of paradigms have been used to examine inhibitory control. In most paradigms, the ability to inhibit a prepotent response is evaluated by comparing reaction time (RT) across two experimental conditions (response compatible and response incompatible). In a response compatible condition, participants respond to target stimuli by generating a prepotent response. In a response incompatible condition, participants generate an oppositional response that requires inhibition of the prepotent response.

A familiar example is the Stroop paradigm. In this paradigm, participants must name the colors in which color words are presented. In the compatible condition, colors and color words are congruent (e.g., *RED* printed in red ink); in the incompatible condition, colors and color words are incongruent (e.g., *RED* printed in blue ink). Color naming is faster in the compatible condition because the prepotent reading response facilitates performance. In contrast, color naming is slower in the incompatible condition because reading must be inhibited.

The reading skills necessary to generate a Stroop effect are not fully developed before the age of 6 or 7 years (Cox, Chee, Chase, & Baumgardner, 1997). For this reason, other paradigms are often used in studies including younger school-age children. For example, we previously used a stimulus–response compatibility paradigm in which children, young adults, and older adults were asked to respond to peripheral targets presented on a computer monitor (Christ et al., 2001). In the compatible condition of our task, participants were asked to make an ipsilateral response (e.g., press a button on the right when a target appeared on the right). In the incompatible condition, participants were asked to make a contralateral response (e.g., press a button on the left when a target appeared on the right). RT was faster in the compatible condition because the same-sided response was prepotent; RT was slower in the incompatible condition because the prepotent same-sided response had to be inhibited. The effect of age on the efficiency of inhibitory control was evaluated by comparing RT in compatible and incompatible conditions for the child, young adult, and older adult groups.

CONVENTIONAL DATA ANALYTIC APPROACHES

Regardless of the paradigm used to assess inhibitory control, the resulting RT data are typically examined using analytic strategies based on measures of central ten-

dency (i.e., means or medians). Consider the scenario in which inhibitory control is hypothesized to be less efficient in older adults compared with young adults. In this instance, an inferential statistical test such as analysis of variance (ANOVA) may be used to determine if mean RT in compatible and incompatible conditions is different for the two age groups. Assuming that the groups have comparable RTs in the compatible condition, a finding of a group by condition interaction verifies the hypothesis of less efficient inhibitory control in older adults.

As suggested by our example, analytic strategies based on measures of central tendency often result in interesting findings. However, these strategies are limited in terms of interpretive power because only one component of the RT distributions is examined (Hockley, 1984; Ratcliff, 1979; Ratcliff & Murdoch, 1976). In the scenario just described, there are two possible reasons for the between-groups difference in mean RT. On the one hand, it is possible that the RT distributions of older and young adults are similar in shape but are shifted along the RT scale relative to one another; for example, as shown in the first panel of Figure 1, the between-groups difference in mean RT could be driven by a general increase in RT for older adults. On the other hand, it is possible that the RT distributions are dissimilar in shape but are similarly positioned along the RT scale; for example, as shown in the second panel of Figure 1, the difference between group means could be due to an increase in skew for older adults, with more observations falling within one tail of this group's RT distribution. Although conventional analytic strategies reveal that RT distributions are different, they do not reveal how RT distributions are different.

It can be equally problematic when between-groups differences are not found using conventional analytic strategies. Analyses based on means from the RT distributions depicted in Figure 2 would fail to reveal significant differences between older and young adults, although the RT distributions are clearly quite different.

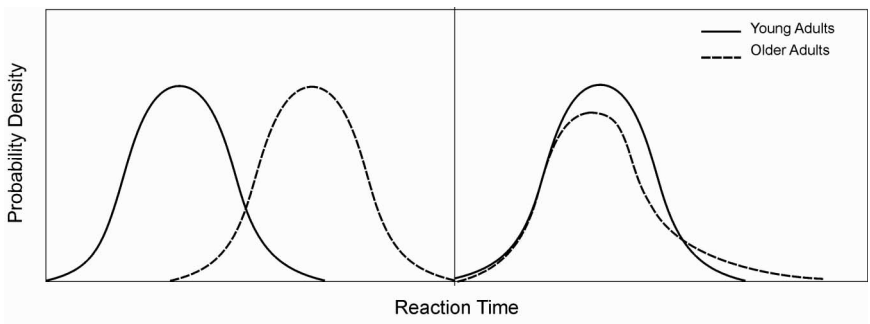

FIGURE 1 Hypothetical reaction time (RT) distributions illustrating a group difference in mean RT between young and older adults. Left panel: The older adult distribution is shifted along the RT scale. Right panel: The older adult distribution is more skewed relative to the young adult distribution.

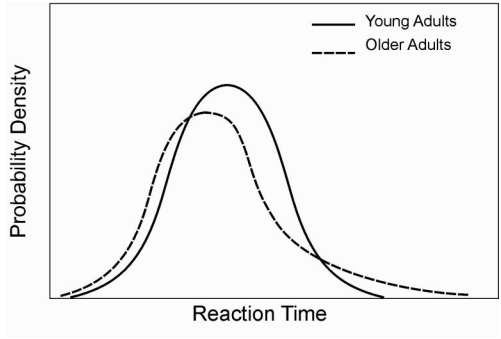

FIGURE 2 Hypothetical reaction time (RT) distributions illustrating no group difference in mean RT. Note that the RT distribution of older adults is shifted in one direction and skewed in the other. As a result of this opposition, mean RT is comparable for young and older adults.

This failure occurs because there are opposing influences on different components of the RT distribution of older adults; the distribution is shifted in one direction and skewed in the other. The net result is that RT means for older and younger adults are comparable.

THE EX-GAUSSIAN APPROACH

To circumvent the loss of interpretive detail that occurs when one is performing statistical analyses based on measures of central tendency, alternative strategies have been developed that more precisely define the shape of RT distributions. One such strategy entails fitting the ex-Gaussian distribution to empirical RT data (Balota & Spieler, 1999; Heathcote, Popiel, & Mewhort, 1991; Spieler, Balota, & Faust, 2000). The ex-Gaussian distribution represents the convolution of two independent functions, a normal function and an exponential function (see Figure 3). In fitting the ex-Gaussian distribution, estimates of three parameters are obtained (mu, sigma, and tau). Mu (μ) represents the mean of the normal function and reflects average performance. Sigma (σ) represents the standard deviation of the normal function and reflects variability in performance. Tau (τ) reflects the mean and standard deviation of the exponential function and reflects extremes in performance.

Conventional values such as means and standard deviations can be expressed as functions of ex-Gaussian parameters (Ratcliff, 1979). As the following formulas illustrate, means (M_{RT}) may be decomposed into μ and τ, and variance (S^2_{RT}) may be decomposed into σ and τ. As a result, it is possible to examine whether an experimental manipulation has a pervasive effect that influences all three ex-Gaussian parameters (i.e., μ, σ, and τ) or a selective effect that influences only a subset of pa-

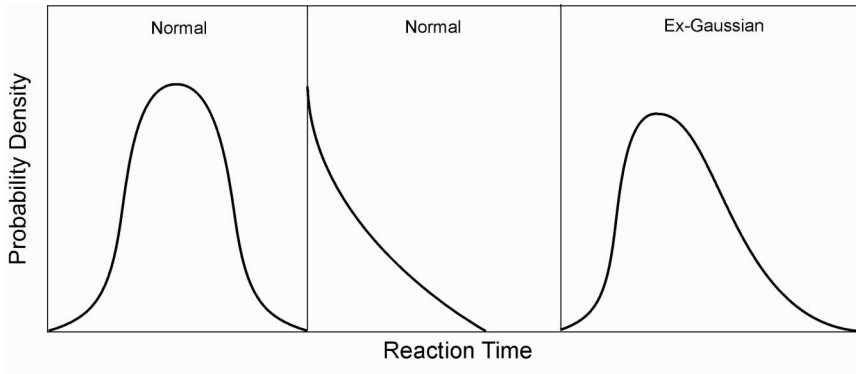

FIGURE 3 Hypothetical probability density functions for a normal distribution, an exponential distribution, and the resulting ex-Gaussian distribution.

rameters (e.g., μ and σ, or only τ). Thus, the ex-Gaussian approach offers greater interpretive power compared to conventional statistical approaches.

$$M_{RT} = \mu + \tau$$
$$S^2_{RT} = \sigma^2 + \tau^2$$

Recent research by West, Murphy, Armilio, Craik, and Stuss (2002) serves to illustrate this point. In this study, tests of memory and attention were administered to young and older adults across multiple test sessions. Using conventional analyses, it was shown that the performance of older adults was more variable than that of young adults. By conducting ex-Gaussian analyses, West et al. demonstrated that the age-related increase in performance variability was related to greater skew in the RT distribution of older adults. These results led to the conclusion that performance variability is increased in older adults because of transient periods of inefficient executive control. As this research exemplifies, the ex-Gaussian approach facilitated a deeper understanding of cognitive changes related to adult aging. We believe this approach will be equally beneficial in understanding changes in cognition that occur during childhood.

RATIONALE FOR THIS STUDY

As mentioned earlier, we previously conducted a study using a stimulus–response compatibility paradigm to evaluate inhibitory control across the life span (Christ et al., 2001). In that study, conventional data analyses (primarily ANOVA) showed that inhibitory control was less efficient for older than young adults but was comparable for children and young adults. The present research represents a reanalysis

of these RT data using both conventional and ex-Gaussian strategies. The rationale of our study was twofold. First, we aimed to exemplify the utility of the ex-Gaussian approach for analyzing RT data in neuropsychological research and to demonstrate that this approach reveals between-groups differences that are not evident using conventional analytic approaches. Second, by using this approach, we aimed to gain further insights into the nature of age-related changes in inhibitory control that occur across the life span. Of particular interest was the reexamination of data that were previously collected with children. We predicted that, using the ex-Gaussian approach, differences in the RT distributions of children and young adults would be identified that were not previously apparent. In addition, we believed that findings resulting from the ex-Gaussian approach would enrich our understanding of the difference in inhibitory control that we previously observed between older and young adults.

Method

Participants. Data from 123 participants recruited from Washington University and the St. Louis community were initially examined. Data from 9 participants were excluded because of poor fits to the ex-Gaussian distribution. The remaining data represented three age groups: child ($n = 37$; 18 boys, 19 girls), young adult ($n = 43$; 7 men, 36 women), and older adult ($n = 33$; 12 men, 21 women). For the child, young adult, and older adult groups, years of age ranged from 6 to 15 ($M = 10.4$, $SD = 2.5$), 17 to 22 ($M = 19.6$, $SD = 1.3$), and 61 to 82 ($M = 72.9$, $SD = 5.6$), respectively. Years of education ranged from 0 to 10 for the child group ($M = 4.6$, $SD = 2.8$), 12 to 15 for the young adult group ($M = 13.2$, $SD = 1.1$), and 8 to 18 for the older adult group ($M = 13.9$, $SD = 2.2$). No participants had histories of mental retardation, learning disorder, dementia, or major medical or psychiatric disorder.

Procedure. Procedural details of the stimulus–response compatibility task have been described in earlier publications (Christ et al., 2001; Christ, White, Brunstrom, & Abrams, 2003). Testing was conducted in a well-illuminated room. Participants were seated in front of a cathode-ray tube display and a panel of three 3-in. (7.62 cm) diameter response buttons. The center response button was aligned with the vertical meridian of the display and the participant's body. The lateral response buttons were located 5 in. (12.7 cm) to the left and right of the center button. At the beginning of each trial, three horizontally aligned circles appeared on the display (diameter = 5º; interstimulus distance = 5º). To initiate the trial, participants pressed the center button for a minimum of 500 msec. Concurrent with depression of the center button, the center circle of the display brightened (i.e., turned blue). Participants were instructed to continue pressing the center button until one of the peripheral circles brightened (i.e., turned gray). The interval between brightening of the center circle and brightening of the peripheral circle varied from 600 to 1,000 msec.

Two experimental conditions were administered, differing only in terms of instructional set. Because stimulus presentation was identical in both conditions, group differences in performance across the two conditions could not be attributed to differences in low-level perceptual ability, visual acuity, or eye movement. In the compatible condition, participants were instructed to press the left response button when the left circle brightened and to press the right response button when the right circle brightened. In the incompatible condition, participants were instructed to press the left response button when the right circle brightened and to press the right response button when the left circle brightened. When a correct response was made, the center circle brightened again and a new trial was initiated with depression of the center button. When an error was made, participants heard a brief tone and an error message appeared on the display. The message *too fast* appeared when a response was made in less than 100 msec after the brightening of a peripheral circle (anticipatory error). The message *too slow* appeared when participants failed to release the center button within 3,000 msec of the brightening of a peripheral circle or when more than 3,000 msec elapsed between release of the center button and depression of a peripheral button (inattention errors). The message *wrong response* appeared when participants pressed the incorrect peripheral button (accuracy errors). All responses were made with the dominant hand.

Twenty practice trials were administered (10 compatible trials followed by 10 incompatible trials). Participants then completed 80 experimental trials in which the two conditions were presented in alternating blocks of 10 trials each. For each block of trials, position was counterbalanced such that brightening was equally likely to occur in the left and right peripheral circles. On each trial, RT and response accuracy were recorded.

Results

Trials on which anticipatory, inattentive, or accuracy errors occurred were excluded from analysis. Because overall error rate was low ($M = 1.7$ %), very few trials were excluded. Frequency histograms for each age group are presented in Figure 4.

Using trials on which correct responses were made, we computed means of raw RTs for each participant in the compatible and incompatible conditions. Ex-Gaussian parameters for each participant were estimated using the statistical package Quantile Maximum Likelihood Estimation (QMLE; Brown & Heathcote, 2003). Mean values of the parameters of interest (mean, standard deviation, μ, σ, and τ) for each age group are presented in Table 1.

Hierarchical regression was used to evaluate the contribution of age group to each parameter. Values from the incompatible condition served as the dependent variable. To control for age-related differences in general processing speed and perceptual ability, we entered values from the compatible condition in the first step

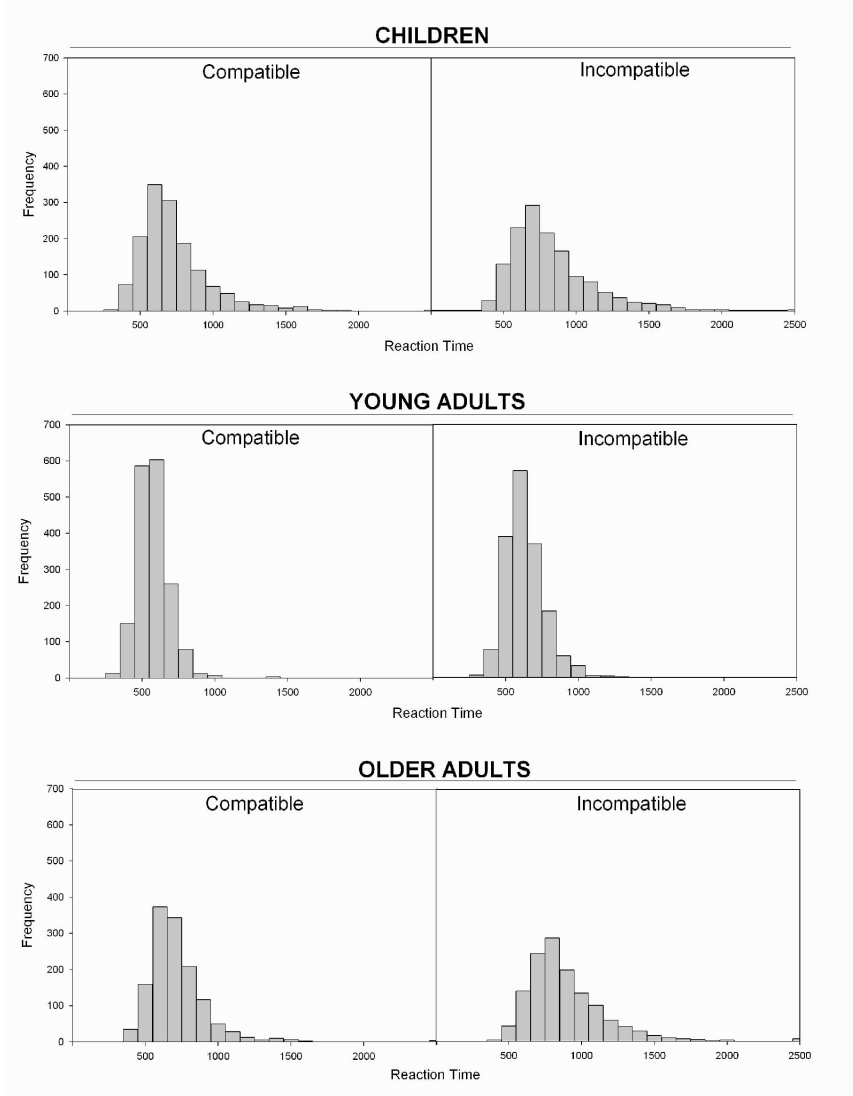

FIGURE 4 Frequency histograms for each age group as a function of experimental condition.

of each regression. We entered group in a second step. To ensure that age differences in general processing speed and perceptual ability were adequately controlled, we entered the interaction between group and values from the compatible condition in a third step. In all analyses, the interaction between group and values from the compatible condition was nonsignificant, indicating that age differences

TABLE 1
Mean Values for Each Age Group as a Function of the Experimental Condition

	Compatible					*Incompatible*				
Group	*M*	*SD*	μ	σ	τ	*M*	*SD*	μ	σ	τ
Child	696	176	545	58	150	788	190	622	66	169
Young adult	528	78	471	36	55	584	88	511	38	73
Older adult	664	143	549	42	113	828	173	689	83	139

in processing speed were adequately controlled; as such, this interaction is not discussed further.

All findings are reported in terms of the unique variance in values from the incompatible condition that is accounted for by group after the contribution of values from the compatible condition has been removed. That is, results from increments in R^2 (i.e., squared partial correlations) are reported. Statistically nonsignificant results reflect findings for which $p > .05$. Results of hierarchical regression analyses are summarized in Table 2.

TABLE 2
Hierarchical Regression Analyses Comparing Child and Older Adult Groups to the Young Adult Group

	Group			
	Child Versus Young Adult		*Older Adult Versus Young Adult*	
Predictor	R^2	ΔR^2	R^2	ΔR^2
Mean				
M compatible	.931		.878	
Age group	.933	.002	.910	.032**
M Compatible × Age Group	.934	.002	.910	.000
μ				
μ compatible	.818		.769	
Age group	.824	.007	.858	.089**
μ Compatible × Age Group	.831	.007	.861	.003
σ				
σ compatible	.312		.288	
Age group	.366	.054*	.594	.306**
σ Compatible × Age Group	.366	.000	.605	.011
τ				
τ compatible	.620		.267	
Age group	.635	.016	.288	.040*
τ Compatible × Age Group	.637	.002	.297	.018

*$p < .05$ for ΔR^2. **$p < .01$.

As a starting point, a conventional data analytic strategy based on means was used to examine possible age-related differences in inhibitory control. In the analyses of data from children and young adults, group failed to account for a significant proportion of variance in RT means. In the analyses of data from older and young adults, group accounted for 3.2% of variance in means ($p < .001$). These findings point to age-related changes in inhibitory control in older adults but not in school-age children.

To more thoroughly examine the identified age-related differences, we submitted ex-Gaussian parameters for analysis. In the analyses of data from children and young adults, group failed to account for a significant proportion of variance in either μ or τ. Group, however, accounted for 5.4% of variance in σ ($p < .05$). In the analyses of data from older and younger adults, group accounted for 8.9% of variance in μ ($p < .001$), 30.6% of variance in σ ($p < .001$), and 4% of variance in τ ($p < .05$).

DISCUSSION

In this study, an ex-Gaussian approach was used to obtain a deeper understanding of age-related changes in inhibitory control. Not only did we find that the inhibitory performance of children and older adults differed from that of young adults but we were able to characterize these differences at a finer level of detail than in previous studies. At the earlier end of the life span, we found that the inhibitory performance of children was more variable (reflected in σ of the RT distribution) than that of young adults. At the later end of the life span, we found that the performance of older adults was slower (reflected in μ), more variable (reflected in σ), and more extreme (reflected in τ) than that of young adults. Although our effects were small, we contend that they are meaningful because they provide additional insights into the nature of age-related changes in inhibitory control. To further this understanding, future studies should be aimed at using the ex-Gaussian approach across a variety of paradigms that assess different aspects of inhibitory ability, including the ability to inhibit responses (e.g., go/no-go and stop-signal paradigms) as well as the ability to inhibit and generate alternate responses (e.g., Stroop paradigms).

As demonstrated here, the ex-Gaussian approach may be used to circumvent some of the limitations of analytic approaches based on measures of central tendency. The ex-Gaussian approach entails fitting a distribution to empirical RT data. Although other distributions may be used for this purpose (e.g., Weibull and Wald), the ex-Gaussian distribution was selected because it provides a good fit to empirical RT data (Heathcote et al., 1991), it can be fit with as few as 40 observations per cell, it may be used by researchers who are not necessarily well-versed in mathematical psychology, and software tools for obtaining fits are readily available (e.g., QMLE). Further, the ex-Gaussian approach has been widely adopted by cognitive researchers (e.g., Andrews & Heathcote, 2001; Balota & Spieler, 1999;

Heathcote et al., 1991; Hockley, 1984; Leth-Steensen, Elbaz, & Douglas, 2000; Mewhort, Braun, & Heathcote, 1992; Ratcliff & Murdock, 1976; Spieler et al., 1996; Wixted & Roher, 1993), facilitating the integration of cognitive and neuropsychological research.

In conclusion, the ex-Gaussian approach offers a number of pragmatic advantages. The chief advantage, however, is increased interpretive power. By decomposing measures of central tendency, it is possible to determine whether the effects of experimental manipulations are attributable to shift (μ), spread (σ), or skew (τ) in RT distributions. Thus, the ex-Gaussian approach provides a tool for analyzing RT data at a finer level of detail than is possible using more conventional analytic strategies. This approach may particularly enrich researchers' understanding of relatively subtle changes in performance that occur across the life span.

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REFERENCES

Andrews, S., & Heathcote, A. (2001). Distinguishing common and task-specific processes in word identification: A matter of some moment? *Journal of Experimental Psychology: Human Perception and Performance, 27,* 514–544.

Balota, D. A., & Spieler, D. H. (1999). Word frequency, repetition, and lexicality effects in word recognition tasks: Beyond measures of central tendency. *Journal of Experimental Psychology: General*, *128,* 32–55.

Brown, S., & Heathcote, A. (2003). QMLE: Fast, robust and efficient estimation of distribution functions based on quantiles. *Behaviour Research Methods, Instruments & Computers, 35,* 485–492.

Carver, A. C., Livesey, D. J., & Charles, M. (2001). Age related changes in inhibitory control as measured by stop signal task performance. *International Journal of Neuroscience, 107*(1–2), 43–61.

Christ, S. E., White, D. A., Brunstrom, J. E., & Abrams, R. A. (2003). Inhibitory control following perinatal brain injury. *Neuropsychology, 17,* 171–178.

Christ, S. E., White, D. A., Mandernach, T., & Keys, B. A. (2001). Inhibitory control across the life-span. *Developmental Neuropsychology, 20,* 653–669.

Cox, C. S., Chee, E., Chase, G. A., & Baumgardner, T. L. (1997). Reading proficiency affects the construct validity of the Stroop test interference score. *Clinical Neuropsychologist, 11*(2), 105–110.

Diamond, A., & Taylor, C. (1996). Development of an aspect of executive control: Development of the abilities to remember what I said and to "do as I say, not as I do." *Developmental Psychobiology, 29,* 315–334.

Durston, S., Thomas, K. M., Yang, Y., Ulug, A. Z., Zimmerman, R. D., & Casey, B. J. (2002). A neural basis for the development of inhibitory control. *Developmental Science, 5*(4), F9–F16.

Gerstadt, C. L., Hong, Y. J., & Diamond, A. (1994). The relationship between cognition and action: Performance of children 3 1/2–7 years old on a Stroop-like day–night test. *Cognition, 53*, 129–153.

Girelli, L., Sandrini, M., Cappa, S., & Butterworth, B. (2001). Number-Stroop performance in normal aging and Alzheimer's-type dementia. *Brain and Cognition, 46*(1–2), 144–149.

Hazeltine, E., Poldrack, R., & Gabrieli, J. D. E. (2000). Neural activation during response competition. *Journal of Cognitive Neuroscience*, *12*(Suppl. 2), 118–129.

Heathcote, A., Popiel, S. J., & Mewhort, D. J. K. (1991). Analysis of response time distributions: An example using the Stroop task. *Psychological Bulletin, 109,* 340–347.

Hockley, W. E. (1984). Analysis of response time distributions in the study of cognitive processes. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10,* 598–615.

Konishi, S., Nakajima, K., Uchida, I., Kikyo, H., Kameyama, M., & Miyashita, Y. (1999). Common inhibitory mechanism in human inferior prefrontal cortex revealed by event-related functional MRI. *Brain, 122*, 981–991.

Kramer, A. F., Humphrey, D. G., Larish, J. F., Logan, G. D., & Strayer, D. L. (1994). Aging and inhibition: Beyond a unitary view of inhibitory processing in attention. *Psychology and Aging, 9,* 491–512.

Krasnegor, N. A., Lyon, G. R., & Goldman-Rakic, P. S. (1997). *Development of prefrontal cortex*. Baltimore: Brooks.

Leth-Steensen, C., Elbaz, Z. K., & Douglas, V. I. (2000). Mean response times, variability and skew in the responding of ADHD children: A response time distributional approach. *Acta Psychologica, 104*(2), 167–190.

Leung, H. C., Skudlarski, P., Gatenby, J. C., Peterson, B. S., & Gore, J. C. (2000). An event-related functional MRI study of the Stroop color word interference task. *Cerebral Cortex*, *10,* 552–560.

Liddle, P. F., Kiehl, K. A., & Smith, A. M. (2001). Event-related fMRI study of response inhibition. *Human Brain Mapping, 12*, 100–109.

Livesey, D. J., & Morgan, G. A. (1991). The development of response inhibition in 4- and 5-year-old children. *Australian Journal of Psychology*, *43*(3), 133–137.

Mewhort, D. J. K., Braun, J. G., & Heathcote, A. (1992). Response-time distributions and the Stroop task: A test of Cohen, Dunbar, and McClelland's (1990) parallel distributed processing model. *Journal of Experimental Psychology: Human Perception and Performance, 18,* 872–882.

Ratcliff, R. (1979). Group reaction time distributions and an analysis of distribution statistics. *Psychological Bulletin, 86,* 446–461.

Ratcliff, R., & Murdock, B. B. (1976). Retrieval processes in recognition memory. *Psychological Review, 83,* 190–214.

Rubia, K., Russell, T., Overmeyer, S., Brammer, M. J., Bullmore, E. T., Sharma, T., et al. (2001). Mapping motor inhibition: Conjunctive brain activations across different versions of go/no-go and stop tasks. *NeuroImage, 13*, 250–261.

Spieler, D. H., Balota, D. A., & Faust, M. E. (1996). Stroop performance in healthy younger and older adults and in individuals with dementia of the Alzheimer's type. *Journal of Experimental Psychology: Human Perception and Performance, 22,* 461–479.

Spieler, D. H., Balota, D. A., & Faust, M. E. (2000). Levels of selective attention revealed through analyses of response time distributions. *Journal of Experimental Psychology: Human Perception and Performance, 26,* 506–526.

Van der Lubbe, R. H. J., & Verleger, R. (2002). Aging and the Simon task. *Psychophysiology, 39*(1), 100–110.

West, R., Murphy, K. J., Armilio, M. L., Craik, F. I., & Stuss, D. T. (2002). Lapses of intention and performance variability reveal age-related increases in fluctuations of executive control. *Brain and Cognition, 49,* 402–419.

Williams, B. R., Ponesse, J. S., Schachar, R. J., Logan, G. D., & Tannock, R. (1999). Development of inhibitory control across the life span. *Developmental Psychology, 35,* 205–213.

Wixted, J. T., & Rohrer, D. (1993). Proactive interference and the dynamics of free recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 1024–1039.

Wright, I., Waterman, M., Prescott, H., & Murdoch-Eaton, D. (2003). A new Stroop-like measure of inhibitory function development: Typical developmental trends. *Journal of Child Psychology and Psychiatry, 44,* 561–575.