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Load and Order in Rapid Automatized Naming: A Large-Scale Prospective Study of Toddlers With Brain Injury

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The rapid automatized naming task (RAN) is a well-established tool to evaluate risk of developmental disorders. Its potential use with 3-year-olds who are at risk for learning difficulties and factors affecting its dependent measures are not yet understood. This study investigated the effects of neonatal central nervous system compromise grouping (five levels, $N = 617$) on RAN task adapted for 3-year-olds, using two levels of information load and two presentation orders. Results showed that increased errors and slowed speed in toddlers are expected subsequent to *severe* neonatal CNS compromise. Furthermore, collaborative information may have a beneficial effect on processing speeds of toddlers born with severe, but not with moderate, neonatal CNS compromise. Finally, the study highlights the feasability of evaluating RAN performance in toddlers who are at a developmental risk for learning disabilities and the conditions of RAN that may facilitate performance of severely affected participants.

Keywords: rapid automatized naming; brain injury; processing speed; high-risk; prematurity

Children who were neonatally diagnosed with severe hypoxic-ischemic related deficits and/or with periventricular leucomalacia are at a significant risk for cognitive deficits, attention disorders, and academic difficulties, particularly, reading disorders (Downie, Frisk, & Jakobson, 2005; Marlow, Rose, Rands, & Draper, 2005) and specific language deficits. Early detection of specific deficits is thus of great importance.

Rapid automatized naming (RAN) that relies upon verbal processing, processing speed, and executive control (EC) has been historically developed as a predictor of reading readiness (Denckla & Rudel, 1976), as one of the concurrent correlates of dyslexia (Wocadlo &

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Rieger, 2007), and an important diagnostic component within the executive control domain (Tannock, Martinussen, & Frijters, 2000). It has been shown that RAN is a sensitive measure in neuropsychological studies and in the domain of developmental pathology of specific populations (Pennington & Ozonoff, 1996; Stahl & Pry, 2005), including phenylketonuria (Huijbregts, de Sonneville, Licht, Sergeant, & van Spronsen, 2002), fetal alcohol spectrum disorder (Simmons, Thomas, Levy, & Riley, 2006), infantile schizophrenia, and autism (Stahl & Pry, 2002).

RAN tasks have good predictive validity to diagnose developmental disorders such as dyslexia (Denckla & Rudel, 1974, 1976; Waber, Wolff, Forbes, & Weiler, 2000; Wolf & Bowers, 1999) and attention and language deficits particularly in children with phonological awareness difficulties (Katz, Curtiss, & Tallal, 1992; Tannock et al., 2000) and attention deficit disorders (Barkley, 1997; Nigg, Hinshaw, Carte, & Treuting, 1998; Rucklidge & Tannock, 2002).

As children with neonatal CNS compromise have been reported to be at risk for these specific developmental disorders (Crespo & Narbona, 2004; Nagy et al., 2003; Vollmer et al., 2003), the current study aimed to test RAN early on in 3-year old toddlers with neonatal BI to examine whether preliminary difficulty markers may be detected with RAN at such an early age.

Little is known on the neural network that is activated in RAN and no large study, to the best of our knowledge, has explored the effects of neonatal BI on RAN behavior. In studies of adults, fMRI studies with RAN tasks have been shown to evoke activation in neural areas associated with eye movement control and attention as well as in a network of structures involved in reading tasks. This reading network includes inferior frontal cortex, temporo-parietal areas, and the ventral visual stream (Misra, Katzir, Wolf, & Poldrack, 2004). Others also reported networks within left frontal and temporal regions (Grönholm et al., 2005; Hirsch et al., 2001). Increased organization of white matter within the left occipital lobe was considered as accounting for task's evolving efficiency (Mabbott, Noseworthy, Bouffet, Laughlin, & Rockel, 2006).

As for the involvement of the inferior prefrontal cortex, perseverative errors have typically been attributed to prefrontal networks (Kolb & Whishaw, 2003; Kubler, Dixon, & Garavan, 2006). The prefrontal network undergoes a significant developmental maturation process that starts in the third trimester of pregnancy (Deipolyi et al., 2005) and progresses through young adulthood (Diamond, 2002), and may therefore be affected by prenatal or neonatal brain injury, which could present as an error increase in RAN tasks.

Even though RAN tests in the first two decades of RAN research assumed error-free performance, RAN has been recently used to study executive control by investigating both processing speeds and errors (Howe, Arnell, Klein, Joanisse, & Tannock, 2006). Slow and variable processing speed is characteristic of children diagnosed with attention or reading deficits, or a combined deficit (Weiler, Bernstein, Bellinger, & Waber, 2000; Weiler, Harris et al., 2000; Willcutt, Pennington, Olson, Chhabildas, & Hulslander, 2005), and in children with low mental competence (Rose, Feldman, Jankowski, & Van Rossem, 2005). These data suggest that RAN may be useful in evaluating children born with neonatal brain insults with suspected inefficient or slow processing. Increased error rates may occur in certain types of neonatal CNS compromise, particularly post severe hypoxic-ischemic events. RAN at an early age may be useful to detect early children who exhibit slowed processing speeds and/or increased error rates in rapid naming tasks. Furthermore, the evaluation should address the conditions under which deficient performance improves.

FACTORS AFFECTING RAN PROCESSING

Factors affecting perseverative performance in young children are not yet well understood. Stimulus-related factors that facilitate (or hamper) efficient continuous processing, evident in RAN, have not yet been discerned. It is generally thought that competitive information increases cognitive load, and it has been reported that the need to process high loads induces greater executive control demand (Lavie, 1995; Lavie & Fox, 2000; Lavie & Tsal, 1994; Velanova, Lustig, Jacoby, & Buckner, 2007). Nevertheless, it is not clear whether it is the competitive nature of the information or the addition of information that induces cognitive load. Load may be one of the primary affecting factors accounting for RAN sensitivity, particularly as a result of neonatal CNS compromise. Some RAN versions have been shown to have a greater executive difficulty than others; however, the effects of added non-competitive information was not yet explored. The study of stimulus-related characteristics should contribute to the search for mechanisms that affect RAN performance in general, and in children with neonatal CNS compromise in particular. This research direction may potentially present conditions that *facilitate* performance of children who are expected to experience a significant difficulty with this task.

To examine load effects on processing in toddlers, it is essential to study primarily the effect of added *non-competing* information. Non-competing information load is defined as the additional information that is of a collaborative nature, distinct from additional information that introduces a conflict, or a Stroop effect.

Different load levels using non-competing information may act to expedite processing due to the presence of extra information, or could hamper it by overwhelming the recipient with unnecessary cues. Understanding under what conditions the effect is beneficial or detrimental may deepen the understanding of the mechanisms involved in supporting efficient processing in children who were diagnosed with neonatal central nervous system brain insult (CNS BI).

Using 5 levels of neonatal CNS BI, this investigation may highlight whether there is a linear relationship between injury severity and deficit magnitude in RAN (i.e., a dose-response relationship), and will contribute to the early identification of children who are at greater risk for later attention, executive, and learning deficits, and those who benefit from certain RAN conditions in order to better tailor intervention programs.

SPECIFIC AIMS OF THE CURRENT STUDY

The primary aim of the current research was to study information load effects on RAN performance in toddlers who were diagnosed neonatally with a CNS BI. The present study aimed to examine whether a dose-response relationship exists between injury severity and compliance, processing speed, and error rates using a simple readily used RAN task; and second, to explore manipulation effects (i.e., order and load) on RAN in toddlers as a function of five levels of neonatal CNS compromise to target conditions that probe more optimal performance in children who are severely affected.

To accomplish these aims we used a RAN task that has been designed specifically for toddlers (Geva, Gardner, & Karmel, 2004). In order to examine the effect of non-competing information on RAN-T, variations in information load (Low and High levels) and in order of information presentation (two orders) were introduced to children who were neonatally diagnosed with brain compromise (5 levels).

Our hypotheses were as follows: 1) neonatal CNS compromise level was expected to be related to increased difficulty, evident in both slowed processing and increased perseveration rate; 2) error rates and speed were expected to interact, and to be affected by, the load level and order of presentation; 3) a processing speed/error tradeoff was anticipated in the mild groups, such that either a reduced speed or increased error rate would be present in these groups; 4) an additional nonlinear effect was hypothesized, such that children with severe CNS impairment were expected to have a particular deficit, evident by marked slower speed compared to children with milder degrees of damage.

METHODS

Research Design

A large subsample was selected from a prospective cohort, with participants from five neonatal CNS compromise groups recruited and classified into groups neonatally and tested at 3 years of age (age corrected for prematurity 34.5 months ± 2 weeks). All testing experimenters were blind to the infants' assigned risk groups. The study was approved by the Institutional Review Board Committees at both St. Vincent's Medical Center, New York and the New York State Institute for Basic Research, New York. Data were obtained in compliance with regulations of both institutions.

Each child was tested using a 2 × 2 repeated measures design. The procedure permitted both the between-subjects effect of neonatal CNS injury level and the within-subject effects of load and order of presentation on outcome measures of RAN-T.

Participants

A cohort of 617 children was recruited from the tertiary care neonatal intensive care unit of St. Vincent's Medical Center Hospital, Staten Island, New York. This cohort is a subsample of a long-term population study on self-regulation of normal and developmentally at-risk newborns. For the purposes of this report, subjects were classified into five neonatal CNS compromise groups based on increasing risk status, as determined during the perinatal period by the worst-case cranial ultrasounds and auditory brain stem evoked responses, based on criteria for group assignment adapted from Karmel, Gardner, Zappulla, and Brown (1987). These relatively low-cost imaging techniques were opted for, despite the risk of under-diagnosis of diffuse damage (Shalak & Perlman, 2002), to allow for a large-scale population study and in order to test the efficacy of procedures that are typically available in most NICU settings around the world for screening of neonatal BI. Grouping criteria are presented in Table 1. Inclusion criteria were recruitment early on in the neonatal period to a long-term prospective study. Participants were recruited from the neonatal and neonatal intensive care units at St. Vincent's Hospital Staten Island, New York. Their worst-case cranial ultrasonographic studies and their worst-case auditory brainstem responses served as classification criteria to the study groups: a control group from the Term nursery (NT), a control group from the NICU (T-NICU), a group with only electrophysiological abnormality on the brainstem evoked responses test and no structural abnormality (ABR-only);

TABLE 1. Central Nervous System Involvement Groups

Group	Neonatal Nursery	Neonatal Risk	Neonatal Inclusion Criteria
Group 1	Normal Newborn Nursery	Low-risk term typical	Term infant recruited from the term nursery; normal neonatal auditory brainstem evoked responses (ABR); too healthy for more than routine clinical evaluation
Group 2	Neonatal Intensive Care Unit (NICU)	NICU typical	Infant recruited from the neonatal intensive care unit; normal neonatal cranial ultrasounds; normal neonatal neonatal auditory brainstem evoked responses
Group 3		ABR only	Infant with no evidence of neonatal CNS injury; normal neonatal cranial ultrasounds, nevertheless diagnosed with an abnormal neonatal auditory brainstem evoked responses (were thus separated from group 2)
Group 4		Mild/moderate insult	Infant diagnosed with a neonatal mild/ moderate intraventricular hemorrhage (IVH, Grade I-III), alone or with subepidural edema or choroid cysts; ventriculomegaly <5 mm
Group 5		Severe insult	Infant diagnosed with a neonatal IVH (Papile Grade III-IV); ventriculomegaly >5 mm; dilatation of third or fourth ventricle; periventricular or parenchymal leukomalacia (LM), porencephaly, hemorrhage or infarct; seizures needing treatment

a group with mild/moderated structural finding (Mild/Mod); and a group with a severe structural finding (Severe). Exclusion criteria were a diagnosis of any genetic abrasions, drug or alcohol exposure and/or postnatal acquired traumatic head injuries. The specific criteria for group inclusion are detailed in Table 1. All participating children spoke English at home.

Epidemiological characteristics with regard to neonatal complications as a function of group are presented in Table 2.

Table 2 shows that CNS brain compromise grouping was related to prematurity, intrauterine growth restriction, and perinatal stress indices, such as elevated APGAR scores. As expected, younger premature infants who were smaller at birth experienced increased perinatal stress and were more prone to greater CNS BI severity. These variables were therefore treated as covariates in the analyses of neonatal CNS compromise effects on outcome. Furthermore, this cohort was characterized by fewer females and more Caucasian

TABLE 2. Neonatal Complications Epidemiology as a Function of Group

Group Measure		NT ($n = 165$)	T-NICU ($n = 184$)	ABR-only* ($n = 135$)	Mild/Moderate ($n = 94$)	Severe ($n = 36$)	*F* test	$p <$
Birth weight (gr)	Mean	3,312	2,720	2,342	1,780	1,895	56.572	0.001
	Range	2,523–4,540	652–4,394	624–4,536	622–3,884	520–4,000		
Gestational age (weeks)	Mean	39.2	37.1	34.7	32.2	32.1	70.143	0.001
	Range	35–42	26–42	26–41	24–41	24–41		
Head circumference (cm)	Mean	34.4	32.6	31.2	29.3	29.0	41.089	0.001
	Range	31–40	24–39	23–38	21–36	21–36		
IUGR index	Mean	0.13	−0.32	−0.02	−0.23	0.15	6.344	0.001
	Range	−1.89 ± 3.34	−3.74 ± 2.81	−2.77 ± 6.96	−3.23 ± 4.13	−3.06 ± 2.49		
Length (cm)	Mean	50.2	47.4	45.0	41.9	41.9	47.914	0.001
	Range	40–56	30–58	30–56	30–54	30–54		
Apgar 1 min	Mean	8.7	7.6	7.4	6.6	5.4	29.735	0.001
	Range	6–9	2–9	2–9	0–9	0–9		
Apgar 5 min	Mean	9.0	8.5	8.2	7.8	7.0	23.962	0.001
	Range	8–10	5–10	4–9	0–9	0–9		
Maternal education (years)	Mean	13.6	13.8	14.1	14.0	12.9	0.615	NS
	Range	0–23	7–22	10–20	9–20	8–18		

Note. NT = typical term (w/o CNS involvement); T-NICU = typical infant from the neonatal intensive care unit (w/o CNS involvement); ABR = auditory brainstem evoked responses; *Abnormality on ABR without additional abnormality on imaging studies; IUGR = intrauterine growth restriction.

TABLE 3. Gender and Cultural Diversity as a Function of Risk Group

Group Measure	NT	T-NICU	ABR-only	Mild/ Moderate	Severe	χ^2 test	*p* <
Gender (%)							
Female	45	51	41	47	47	43.68	0.001
Ethnicity (%)						65.60	0.001
Black	39	34	31	19	28		
Hispanic	12	10	8	11	8		
Caucasian	45	51	58	66	58		
Other	3	4	4	4	6		

TABLE 4. Tests of Multivariate Analysis With Repeated RAN Speed and Error Measures as a Function of Neonatal Risk Variables and Concurrent Competence

Sources	*F*	Sig. <	Partial Eta Squared
Significant within-subject effects			
Errors[a]* Neonatal CNS BI level	2.551	0.039	0.024
Errors* Order	14.652	0.001	0.037
Errors* Speed* Order	5.585	0.019	0.013
Speed* Neonatal CNS BI level	2.949	0.020	0.027
Speed[b]	20.105	0.001	0.046
Speed* Order* Gender	4.604	0.032	0.011
Speed* DQ	16.067	0.001	0.037
Speed* Order	2.110	0.001	0.037
Significant between-subject effects			
Neonatal CNS BI level	3.289	0.011	0.031
DQ	23.403	0.000	0.053

[a]Repeated measures term of completion times (seconds) for boards low load and H.
[b]Repeated measures term for errors on boards low load and H.

children in the more compromised groups (Table 3); these factors were thus entered as covariates as well.

RAN-T Measure

The RAN-T task is essentially a nonselective verbal alternation task. The task, constructed to be appropriate for 3 years of age, required the child to name series of randomly ordered visual cues (Figure 1). The task was particularly adapted for children who are suspected of experiencing developmental difficulties. It is relatively short, elicits relatively low arousal, and does not present the child with any restricting rules (or "do nots"), so as not to stimulate non-compliance.

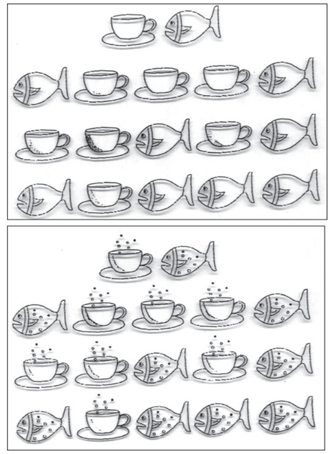

FIGURE 1. Low and high load Rapid Automatized Naming Task (RAN-T) stimulus boards.

Each participant was asked to rapidly name two series of randomly ordered illustrations of two common objects (namely, "fish" and "cup"). These items were selected since it was important to keep the weightings of vocabulary and working memory loads to a minimum as much as possible (Lavie & Tsal, 1994; Lui & Tannock, 2007). Due to wide variability in the scope of vocabulary and working memory capacity in 3-year-old children, the RAN-T for this age group included items presumed to be already over-learned or to be a part of the core vocabulary of younger children. The two particular items, "fish" and "cup," were chosen, as both are high frequency, one-syllable words that limit discrimination against children with language delays or specific language impairments (Brizzolara et al., 2006). These items are typically found in the vocabularies of children who have a mean utterance length of 1.0–2.0. Anecdotal data cited by Clark (1993) suggests that both items are in the language production protocols of 1-year-olds.

Finally, the number of different items to be named was reduced to a minimum, two, in order to ensure that the load on the working memory was age-appropriate (Lavie & Tsal, 1994).

The RAN-T was evaluated with two stimuli boards: a low load board (L) and high load board (H). Each contained a series of 15 stimuli: pictures of the two familiar items, a fish and a cup, organized in a random order in three equal rows on an 8.5×11-inch stimulus board (Figure 1). The two objects were depicted in line drawings, with similar style and equal amount of detail. Non-competing load was introduced in the form of seven bubbles that were each 2 mm in diameter (five empty ones and two blackened ones), representing air bubbles or a pattern on the back of each fish. The same configuration of bubbles, rotated at 90 degrees depicted hot vapor emanating from each cup. Children were required to rapidly and sequentially name the pictures.

Procedure

Each child was tested individually. Children with visual and/or hearing handicaps were tested with their glasses and hearing aids.

Prior to seeing the board, the child was asked to name each of the two stimuli in isolation to ensure correct naming. Whenever naming was hesitant or incorrect, five pair trials were added to ensure familiarity with executing this naming set. Despite the heterogeneity of the sample and the vast diversity of competences, this was extremely rare. Responses were coded for naming accuracy rather than expression accuracy. Therefore, articulation deficits were not considered as an excluding criterion.

Stimuli sets were presented in one of two possible orders, with order of presentation randomized among the children as follows: Order 1 = low load first and high load second; Order 2 = high load first and low load second.

Dependent measures were speed in seconds and number of errors. Errors were coded whenever a participant named a fish as 'cup' or a cup as 'fish'. Other utterances or behaviors were recorded but were not counted as perseverative errors.

The Griffiths Mental Development Scales (GMDS; Griffiths, 1984) were administered to evaluate intelligence quotient (IQ). The GMDS was selected because it is designed specifically to evaluate developmentally at-risk populations and is highly useful with cohorts of preterms with severe brain lesions (Cioni et al., 2000; Dyet et al., 2006). RAN-T was administered after the name attack component of the Hearing and Speech Scale of the GMDS to reduce instructions to a minimum and to facilitate a speeded naming set. Total RAN administration time was typically less than 2 min.

RESULTS

Compliance Rates

Most participants were able to understand and complete the task. A total of 4.91% (for order 1) and 9% (for order 2) were judged by the experimenters as unable to cope with the task, or refusing to cooperate with the experimenters. An additional 16.2% (for order 1) and 22.9% (for order 2) attempted to comply, but were unable to complete the full set of stimuli. The remainder of this high-risk cohort (78.7% and 68%, respectively) completed the full protocol.

A Chi square analysis was conducted to examine whether compliance was dependent upon neonatal CNS compromise risk severity grouping (Figure 2). Analysis showed that severity of neonatal CNS brain injury involvement was related to compliance, such that severely involved children were less likely to perform and more likely to fail to complete the task (Pearson Chi square = 24.4, $p < 0.002$).

Errors

Average error rates on the low load board were 1.58 and 1.20 when presented first and second, respectively, and average error rates on the high load board were 1.14 and 2.01 for first and second presentations, respectively. That is, error rate on the high load board was affected by order, such that it was lower than that of the low load board when it was presented first, and it *doubled* when it was presented second (ANOVA with repeated measures $F = 58.202$, $p < .001$).

The MANCOVA with DQs of the GMDS entered as a covariate revealed a significant three-way interaction of order, with load as a function of neonatal CNS compromise level (Figure 3). The interaction was such that fewer errors were typically made when high load was presented first than when low load was presented first, or when high load was presented

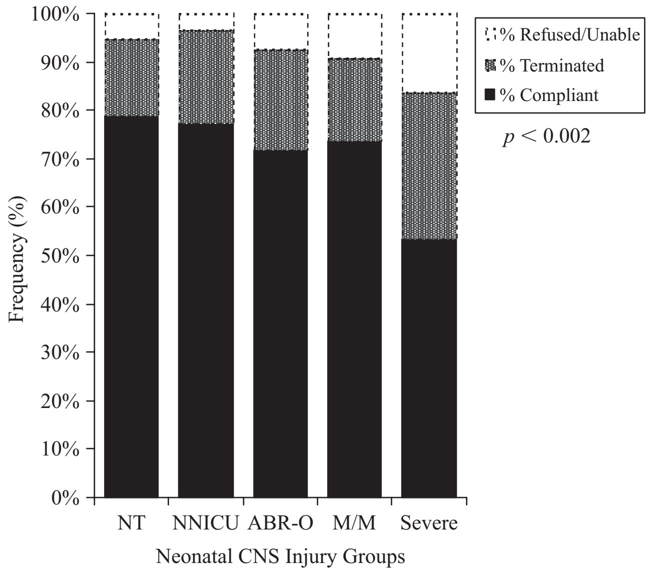

FIGURE 2. RAN-T compliance rates across central nervous system groups.

second (Order 1 vs. Order 2). This interaction was dependent upon neonatal CNS compromise level, such that neonatal CNS compromise level increased the effect of order by load interaction on perseverative errors ($F = 3.36$, $p < 0.01$, partial $\eta^2 = 0.03$). We then conducted post hoc tests. Analysis was indicative of both a linear effect ($p < 0.012$) and a quadratic effect ($p < 0.002$) on errors at the low load and high load boards. The quadratic effect was accounted for by children with severe CNS, who erred more often on both boards, but unlike other risk groups, they *benefited* from the extra non-competing load by making fewer errors when high load was presented first, relative to performing on low load first.

Speed

Overall, average completion speeds of the low load board were similar irrespective of order (mean 34.39 s and mean 35.73 s when presented 1st and 2nd, respectively); Average completion times of the high load board were affected by order, such that average speeds remained similar to low load board times when it was presented first (mean = 34.85 s), but average performance slowed to 37.48 s when it was presented second ($F = 8.422$, $p < .004$).

GLM with repeated measures with gestation age, birth weight, neonatal head circumference, and developmental quotient at 3 years of age, showed that the group with severe CNS compromise took significantly longer to complete the low load board (Least Square Mean time was 58.1 s, Figure 4). Their average speed per stimulus was 65% longer than that of the other risk groups (3.8 s versus 2.3 s, respectively). Post hoc comparisons indicated that the group with severe CNS compromise performed differently than the other participating groups (post hoc group speed differences $F = 4.216$, $p < 0.002$). Children in the severe group took significantly longer to complete the full set than did other groups, but in this respect their pattern across orders and load was no different from the other groups' patterns.

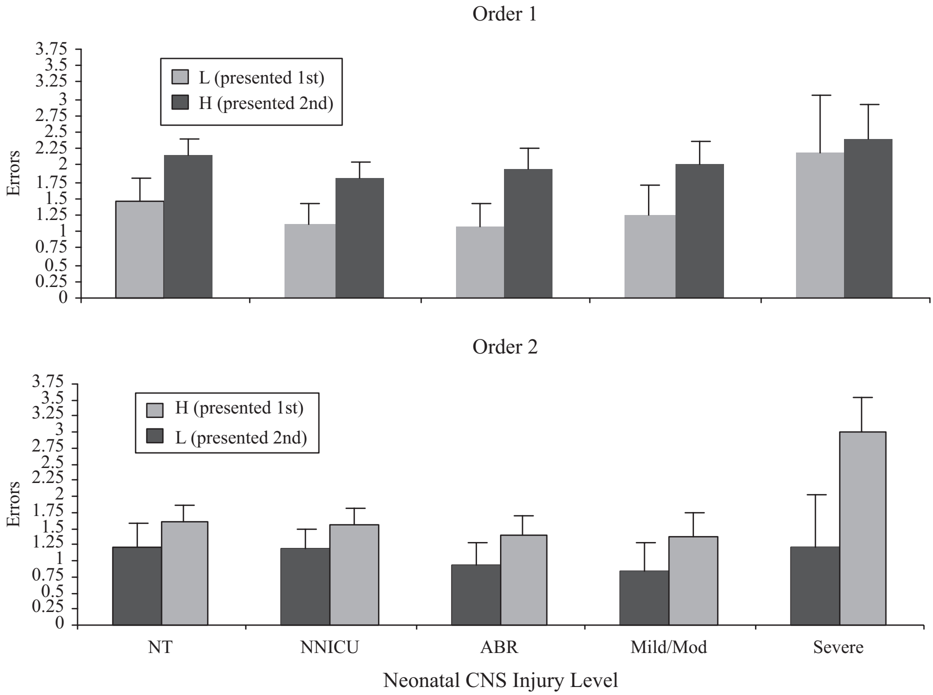

FIGURE 3. Mean number of perseverative errors for low and high load information boards as a function of order of presentation across central nervous system groups.

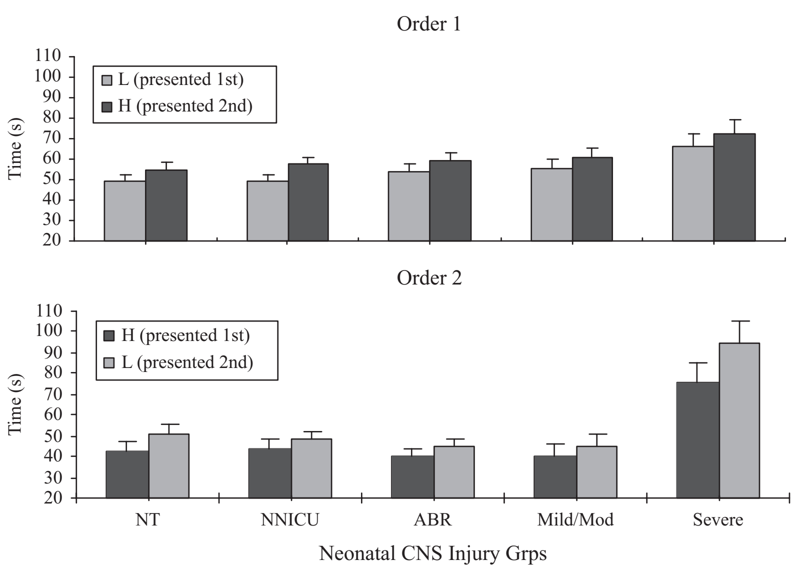

FIGURE 4. Mean time (seconds) for low and high load information boards as a function of order of presentation across central nervous system groups.

Order and Load Interaction Effect on Errors and Speed as a Function of Groups

In order to test for the effects of neonatal CNS BI grouping (5 levels) on error by measuring speed tradeoff as a function of load (2 levels) and order (2 orders), a mega-general linear model with repeated measures was used. To adjust for birth weight differences between groups, neonatal head circumference, Apgar score, and the developmental quotient at the time of testing, these factors were entered as covariates in the model. The model was highly significant (Table 4).

As indicated in Table 4, the analysis of within-subject effects was indicative of eight significant terms. First, two second-order interactions were found: a speed × order × gender interaction, such that speed differences were more affected in boys than in girls by order of presentation. The second second-order interaction showed that the degree of speed/error trade-off was dependent upon order; the affect of difference in speed on difference in error rate was more pronounced in order 1, in which low load was processed first, compared to order 2, in which high load was processed first. Furthermore, it was also found that error differences were dependent upon the level of CNS BI, such that error rates increased as the risk increased. Errors were also dependent upon order such that overall, irrespective of load, more errors were typically made on the second board than on the first. As expected, speed differences were found as a function of load. Speed also interacted with order, such that it was slower overall in Order 1 than in Order 2. Speed differences were dependent upon the degree of neonatal CNS BI in addition to its interaction with the concurrent developmental quotient. Finally, the between-subject effects, neonatal CNS BI level and developmental quotients at 3 years, were found to exert significant main effects on performance. The effects of all other prematurity covariates in the full model (birth weight, gestation age, Apgar scores, and gender) and their interactions with order and gender were not significant.

DISCUSSION

To the best of our knowledge, this is the first study that examines factors affecting RAN in high-risk toddlers at 3 years of age. Our first aim was to study whether 3-year-old children with neonatal CNS compromise are able to perform an adapted RAN-T task using compliance, errors, and speed as dependent measures. It was shown that the task is feasible for a highly varied cohort that has both low- and high-risk participants. The majority of children, most with neonatal CNS compromise, complied fully with this task. Difficulty to cope with the task, when present, was a valuable piece of information on its own: Compliance was related to level of neonatal BI. Since performance difficulties may arise from different sources, such as word retrieval difficulties, dysarthria, attention dysregulation, and emotional dysregulation, to name a few, these data may suggest that use of compliance as a marker of a deficit, which may warrant further attention, should not be over looked.

The second aim of the study was to explore the effects of added non-competing load on information processing in young toddlers who are at developmental risk. The results indicate that load affects performance as a function of the stimuli presentation order of RAN boards, affecting speed and number of errors as a function of the level of the neonatal CNS BI level. The effect was such that low load was processed more quickly and with fewer errors when it was presented first, but was more difficult than high load when it was processed second.

This study points to the importance of non-competing information load embedded in the presented RAN stimuli during automatized naming tasks. When presented first, added stimuli can *facilitate* processing. It can enable a severely affected child to perform faster with fewer errors. At the same time, added information may not be necessary for less affected children. Typical and mildly affected children could process the added information, but did not benefit from it to process the stimuli faster or with less errors.

The effect of load by order on processing speed and on errors seems to support the study's hypothesis. We hypothesized that both processing speed deficit and perseverative errors are related to a common pathogenic process (Willcutt et al., 2005). The current results suggest that neonatal CNS BI, particularly when severe and involving loss of parenchymal tissue, may be especially sensitive to these deficits.

Do the effects observed represent a dose response phenomenon? That is, do the effects seen in the present data set reflect a linear phenomenon, whereby the greater the degree of neonatal injury the more severe the RAN-T deficit, or do they signify a quadratic effect, whereby a deficit should be anticipated only beyond a certain severity of parenchymal loss? The results seem to better support the latter hypothesis. RAN-T appears to be less sensitive to various minor neonatal BI, and is very affected by severe neonatal BI. In this sense, the group with severe CNS compromise was affected in a dose-dependent manner; however, these children also presented an additional unique pattern. Children in the severe neonatal CNS compromise group were less likely to succeed in completing the RAN-T, and if they did succeed in completing the task, they were affected mostly by degrees of added collaborative information and by order of presentation.

This effect of load and order on children in the severe group seems to be compatible with a hypothesis that their systems benefitted form collaborative information. Moreover, it was noted that the beneficial effect, faster performance, and fewer errors was evident when added information was presented first, that is, well within their sustained attention capacity, such that it was less likely to occur when it was presented second. This may be accounted for by shortened sustained attention capacity of the participants, particularly boys in the severe group.

Children in the severe neonatal CNS compromise group having to process the high load stimulus second made them try to hurry through the set, and this evoked an impulsive pattern of performance, resulting in many more errors. Thus, the timing of presenting a high load stimulus to severely affected children may play a significant role in their performance of timed tasks, it may be beneficial to introduce these stimuli first and reserve lower load stimuli to a later phase in the testing session. These findings may be harnessed for clinical/pedagogic work directed toward limiting impulsive performance in children, particularly boys with severe neonatal CNS compromise.

Analysis of the current findings also allowed for exploration of whether the difficulties documented are related to prematurity or are better accounted for by perinatal CNS compromise that accompanies infants at partum (Aylward, 2005; Gardner, 2005). Results point to the potency of CNS BI severity, rather than prematurity or other perinatal risk factors, in accounting for RAN difficulties at 3 years of age (Ewing-Cobbs, Prasad, Landry, Kramer, & DeLeon, 2004; Graham, Gennarelli, & McIntosh, 2002; Levin, Song, Ewing-Cobbs, Chapman, & Mendelsohn, 2001). On the whole, the data presented in the current study seem to implicate CNS BI foremost as a main effect, and also as an interacting component that affects the efficiency of speed × error regulation trade-off across conditions. This may indicate that the early emerging selection process required to process high loads is susceptible to neonatal complications that often *accompany* prematurity rather than to prematurity, per se.

A social policy point that is warranted here has to do with the efficacy of relatively low cost diagnostic tools, such as cranial ultra-sound and paper-and-pencil neuropsychological tests. The present data is feasible on a large data set in part due to the relative low costs of these procedures. Cranial ultrasonography is more readily available in most NICUs and follow-up clinics around the world. Use of a simple paper-and-pencil test that requires 3 minutes to administer is a user-friendly tool that may be useful in multiple preschools settings with diverse populations.

For educators, in view of usefulness of evaluating rapid naming as part of reading readiness evaluations, the study highlights the usefulness of RAN-T for screening rapid naming in large populations and targeting children at preschool and kindergarten who may exhibit deficits early. The RAN-T may be used as part of a psycho-didactic pre schoolers' evaluation. It may be used with 3-year-olds to evaluate whether a child tends to have difficulties naming rapidly. Crude criteria that may serve as warning signals and warrant further evaluation are: 1) difficulty to complete the task; 2) making 3 or more errors on any board; and/or, 3) taking 40 s or longer to complete naming a board. Finally, RAN-T may serve to evaluate whether under certain testing conditions, a child can perform more efficiently (with added information or without it), thus adding another component to the evaluation to improve the efficacy of an early psycho-didactic remediation plan.

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