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## **Assistive and Instructional Technology**

**By Brian Bryant, PhD**

For several years, we have been examining the role of assistive technology (AT) as it applies to multiple facets of life for people with various disabilities (Bryant & Bryant, 2011; Bryant, Bryant, & Rieth, 2002; Bryant, & Seay, 1998; Bryant, Seay, & Bryant, 1999). We often quote the line that appeared in a 1991 International Business Machine (IBM) AT training program: “For people without disabilities, technology makes things easier. For people with disabilities, technology makes things possible” (p. 2). In our Assistive and Instructional Technology Lab in the College of Education at The University of Texas at Austin (<http://www.edb.utexas.edu/ATLab/index.php>), we have a variety of scenarios for demonstrating how AT can promote equity in the classroom, in the home, at the workplace, and in early childhood play. These scenarios simulate how AT devices can be used to promote equity across the lifespan and in various contexts. More than 500 graduate and undergraduate students annually participate in 2-hour tours of the lab to see how AT can provide access to life’s offerings. These sessions include hands-on activities that allow the students a chance to see for themselves the value of AT devices and services.

In the classroom, AT can supplement Universal Design for Learning (UDL) lessons or serve as a means for students with disabilities to access the general education curriculum. We are currently conducting research that examines the value of applications (i.e., apps) as educational tools that enhance instruction, and we demonstrate apps on mobile devices so that visitors to the lab can see how apps can benefit students, whether they have disabilities or not. We also present learning centers that have been designed with UDL guidelines and principles (CAST, 2010) in mind.

In the home, we simulate AT devices for the kitchen, lavatory, and living room/study to show how the devices promote independent living. Many of the students comment on how their grandparents could use the devices to help them remain in their homes as they continue to age. This is in keeping with our thinking that AT devices should be considered as potential solutions to everyday challenges, and not necessary considered in terms of the person's disability category.

In the workplace, our scenarios include a female accountant who has sustained a traumatic brain injury, a pair of small business owners, one of whom is deaf and one who sustained a spinal cord injury while serving in the military. How do AT devices and services help them remain productive in their small engineering consultancy company? The third scenario is an office worker who is blind and how he uses AT devices to be a successful contributor to his company's operation.

In the early childhood area, we have a number of adaptive toys and games that allow children with disabilities to play alongside their nondisabled friends. Because play is vital to develop fine and gross motor skills, cognitive skills, social skills, and language skills, we discuss the children's toys and games in those contexts.

AT devices are also helpful when providing support services to adults with developmental and/or intellectual disabilities (Bryant, Seok, Ok, & Bryant, 2012). We are just beginning to conduct research to validate AT's potential in support provision, but we are confident that AT devices and service can promote independent living.

In our research using applications (Bryant et al., in review), we are comparing traditional instruction with traditional teacher-directed instruction with fourth graders who have learning disabilities. Our work in reading, writing, and mathematics demonstrates the value of

applications to help promote access to the general education curriculum, although much research is needed to demonstrate the best combination of approaches will promote accessibility.

When examining AT devices, it is important to recognize the importance of the person-technology match. AT devices are not “one size fits all.” One important AT service is conducting assessments for AT in a person’s customary environment, that is, where the students attend classes, where they work, and so forth. We often hear of parents seeing a particular device advertised or used by a student and requesting that the device be purchased for their child. It could be that the device would be a good match for their child, but it could just as well be that the device is not a good match. Only a thorough assessment can result in a positive person-technology fit, so it is important for teachers and parents to become familiar with the assessment process and to play a major role as AT team members. We also encourage people to be educated consumers and to carefully consider the various contexts within which AT devices will be used. Finally, it is important that the assessments be ongoing, because children grow and contexts change, so a device that is a match now may not be as good a match over time.

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# **Overview of Epidemiological Studies of Incidence of Learning Disabilities with Annotated Research References from the Mayo Clinic, Rochester, MN**

By Robert C. Colligan, PhD and Slavica K. Katusic, MD

## **Section I. Introduction**

Careful study design and analyses of the characteristics of the population being studied are essential so the results can be applied to other communities. In the science of epidemiology, establishing and using a birth cohort for research is a powerful scientific tool. A birth cohort is defined as all children who were born to mothers living in a carefully outlined geographic area. There are good reasons why the results from a study done with a birth cohort provide stronger research evidence than other kinds of studies.

First, all of the children in a birth cohort, regardless of their SES, gender, ethnic group and other factors, are equally considered for study. Thus, biases related to other ways in which children can be selected for research (eg, from school referrals, or children evaluated by a psychiatrist, psychologist or pediatrician). Second, each child in the birth cohort has a chance (probability) of having the potential risk factors for the condition being studied (in this case, LDs). These 2 factors allow for the entire range of severity for that condition to be examined (eg, from severe LD to recovered-LD). However, children who are in the birth cohort may not continue to live in that community after birth, since families often move. Therefore, it is important to learn whether or not the children and families who remained in the community are different in some systematic ways from those who moved away (eg, did younger families move?...or more families with girls move? ...or those of lower SES?). If there are no significant differences between those who moved and those who stayed, on important characteristics such

as SES, gender, birth weight, medical conditions, etc... then we can be confident our findings represent the entire birth cohort (the population to be studied), and are not just describing the children and families who stayed.

## **Section II. Annotated Article on the Birth Cohort**

The article listed below describes how our birth cohort (n=8,548 children) was formed. We also describe how it was studied, before we started our LD research. We evaluated our birth cohort with the preceding factors in mind. First, we learned that about 32% of the original birth cohort moved away before age 5 (ie, the typical age for starting Kg in MN). However, this left us with a sufficiently large sample of school-aged children (n=5,718 children) for the kinds of LD studies we were considering. The samples were also large enough to allow separate analyses by gender ( 2,762 girls, 2,956 boys).

### *Potential influence of migration bias in birth cohort studies.*

By Katusic SK, Colligan RC, Barbaresi WJ, Schaid DJ, Jacobsen SJ.

Mayo Clin Proc 1998; 73: 1053-62.

From the study of our birth cohort (the population to be studied for childhood LD), here is what we learned: After comparing the children and families who left the community (emigrated) with those who remained, on more than 25 variables (eg, including things such as age and education of parents at the time their children were born, Apgar scores at birth, birth weight, need for placement in the neonatal ICU, ethnicity, complications of pregnancy/labor/delivery, congenital defects) we learned the following: Parents who moved had slightly higher levels of education (ie, median 14yrs for mothers, 16 for fathers) than those who stayed (median 13yrs for mothers, 14 for fathers), probably because of the training programs and educational opportunities in this area. However, there were no other significant differences germane to LD between those who moved and those who remained in the community.

### Section III. Reading LD in the Birth Cohort

1. Katusic SK, Colligan RC, Barbaresi WJ, Schaid DJ, Jacobsen SJ. Incidence of reading disability in a population-based birth cohort, 1976-1982, Rochester, Minnesota. *Mayo Clin Proc* 2001;76:1081-92.
2. St. Sauver JL, Katusic SK, Barbaresi WJ, Colligan RC, Jacobsen SJ. Boy/girl differences in risk for reading disability: Potential clues? *Am J Epidemiol* 2001;154:787-94.
3. Katusic SK, Barbaresi WJ, Colligan RC, Weaver AL, Leibson CL, Jacobsen SJ. Case definition in epidemiologic studies of AD/HD. *Ann Epidemiol* 2005;15(6):430-7.
4. Yoshimasu K, Barbaresi WJ, Colligan RC, Killian JM, Voigt RG, Weaver AL, Katusic SK. Gender, ADHD, and reading disability in a population-based birth cohort. *Pediatrics* 2010;126:e788-e795. PMID: PMC3098618.

From these 4 studies of Reading Disability (RD), here is what we learned:

- a. Because there is controversy over diagnostic and classification criteria for RD, we used 3 widely reported, different, psychometric algorithms were to classify each student ( 2 discrepancy algorithms—absolute, regression; 1 Low-Average-Achievement)
- b. It is important to use all available information from medical histories, public and private school records, and private tutoring agencies.
- c. Cumulative incidence of RD (from Kg--grade 12) ranged from a low of 5.3% to 11.8% depending on the classification formula applied.
- d. Boys were 2 to 3 times more likely to be classified as RD than girls, regardless of the identification method.
- e. Using children with RD, and children who did not have RD as matched controls, we found that boys and girls may have differential susceptibility to the risk factors for RD.

For example, girls of low birth weight (LBW) were more likely than boys of LBW to have RD. Low maternal educational level was a risk factor for RD among girls (but not for boys). However, for boys, low paternal educational level was a risk factor for RD (but not for girls).

- f. The risk for RD is much greater among boys and girls with ADHD (51% for boys, 48% for girls).

#### **Section IV. Written-Language LD (WLD) in the Birth Cohort**

1. Katusic SK, Colligan RC, Weaver AL, Barbaresi WJ. The Forgotten Learning Disability – Epidemiology of Written Language Disorder in a population-based birth cohort (1976-1982), Rochester, Minnesota. *Pediatrics* 2009;123:1306-13. PMID: PMC2923476.
2. Stoeckel RE, Colligan RC, Barbaresi WJ, Weaver AL, Killian JM, Katusic SK. Early speech-language impairment and risk for written language disorder: a population-based study. *J Dev Behav Pediatr* 2013;34:38-44. PMID: PMC354652953
3. Yoshimasu K, Barbaresi WJ, Colligan R, Killian J, Voigt RG, Weaver A, Katusic S. Written-language disorder in children with and without attention-deficit/hyperactivity disorder in a population-based birth cohort. *Pediatrics* 2011;128(3):e605-12. PMID: PMC33164095

From these 3 studies of Written Language Disability (WLD), we learned:

- a. There is lack of agreement over diagnostic and classification criteria for WLD. Hence, we used 3 different psychometric algorithms to classify each student (2 discrepancy algorithms—absolute, regression; 1 Low--Average--Achievement)
- b. It is important to use all available information from medical, school, and private tutoring records.

- c. Cumulative incidence of RD (from Kg--grade 12) ranged from a low of 6.9.% to 14.7% depending on the classification formula applied.
- d. Just as with RD, boys were 2 to 3 times more likely to be classified with a WLD than girls, regardless of the identification method.
- e. Interestingly, of those with WLD, only about 25% did not have a co-occurring RD.
- f. Not surprisingly, we also found that nearly 70% of the children with WLD had a combination of problems with grammar, spelling, poor handwriting, and sentence construction. However, only about 5% had only handwriting problems, and 13% had only spelling problems.
- g. Boys and girls with a history of speech-language impairment (S/LI) were at increased risk for a WLD (cumulative incidence of WLD was 9% for boys and 9% for girls) compared with children who did not have a history of S/LI.
- h. The presence of a RD increased the risk of a WLD. Among children with S/LI---who also had a RD---the cumulative incidence of a WLD was much greater (52% for boys; 46% for girls) than for boys and girls not having a RD.
- i. Finally, among children with ADHD, the cumulative incidence of WLD was significantly higher for boys (65%) and girls (57%) than for children without ADHD.

#### **Section V. Math Learning Disability (MLD) in the Birth Cohort**

1. Barbaresi WJ, Katusic SK, Colligan RC, Weaver AL, Jacobsen SJ. Math learning disorder: incidence in a population-based birth cohort, 1976-82, Rochester, Minn. *Ambul Pediatr* 2005;5:281-9.

From this study of Math Learning Disability (MLD), we learned:

- a. Just as with RD and WLD, there is no consensus for diagnostic and classification criteria for MLD. Therefore, as with our studies of RD and WLD, we used 3 different psychometric algorithms to classify each student( 2 discrepancy algorithms—absolute, regression; 1 Low-Average-Achievement).
- b. The cumulative incidence of MLD (from Kg--grade 12) ranged from a low of 5.9.% to 13.8% depending on the classification formula applied.
- c. Boys were 1.6 to 2.2 times more likely to be classified with a MLD than girls.
- d. Many children with MLD (35-57%) did not have a co-occurring RD.

## **Section VI. Young Adult LD: Long-Term Follow-Up of Pure Childhood LD in the Birth Cohort**

- a. What happens to children with a RD when they grow up and are in the workforce?
- b. No one seems to know for sure. Many follow up studies to answer that question have been done in the past 50 years. Interestingly, there have been so many follow up studies of RD that summaries of such studies have been published---in fact, there are now six reviews of follow up research on the various LDs.
- c. However, all of these reviews identified significant weaknesses in this research; indeed, to the point that cast doubt on the accuracy of the results.
- d. The problems they found in these studies were worrisome. For example, follow up studies of RD often did not include reading test scores at baseline, nor were there indices for RD severity; furthermore, a lack of face-to-face measures of reading skills at follow up was common; sometimes, so called "long term follow up" studies were actually started and completed while the students were still in school, and so on.

- e. Two significant points emerged from these reviews. First, the early LD follow up studies emphasized the persistent nature of the LDs, particularly RD, into adulthood, even after strong remedial efforts, often over several years, had been made. Second, while a child might have met criteria for a RD, more recent follow up research alluded to the presence of co-existing and significant academic deficits in other core areas, a sort of adverse academic spread-of-effect.
- f. We decided to complete a pilot LD follow up project, using children with research-identified LD from our birth cohort, to learn what had happened to them as young adults.
- g. Our LD follow-up (completed about 15-18 years after the LD was first identified) was intended to avoid the research problems listed above by recruiting participants who, as children, had a "Pure" LD. In that way we would avoid many of the circumstances that potentially could have affected the learning and mastery of basic academic skills.
- h. To have a "Pure LD" (PLD) meant, for our research, that our elementary school students, now young adults (24-25 years of age on average at the time we followed up with them), did not have any of the potentially handicapping conditions mentioned in the 1975 Federal legislation (PL94-142, Education for All Handicapped Children Act) and all of its subsequent modifications.
- i. We applying these factors to electronically screen our birth cohort, using a combination of school and medical information. In this manner we identified a subset of children with various LDs (average age 8-9 years at the time they were classified as LD) for whom there were no medical nor psychological conditions that might have interfered with learning and mastery. These children were classified as having a "Pure LD." For example, this subset of children (n=163) was free of documented visual/hearing or motor

conditions, psychological/psychiatric disorders, were not classified as Mild/Moderate MR (ID), did not have ADHD, nor were there SES factors (e.g., parent education of grade 9 or less), environmental factors (e.g., history of child abuse), cultural nor economic influences of adverse significance.

- j. At the time of follow up, formal psychometric measures of cognitive, memory, visual-perceptual functioning, and basic academic skills were administered. We were able to recruit n=48 young adult participants (N=18 females; 30 males).
- k. Before looking at the outcomes of the young-adult LD assessment, we compared the group of young adults who came for the follow up evaluation, with the young adults who did not. There were no significant childhood differences between the 2 groups on cognitive abilities, academic skills, gender, proportion receiving an IEP or other tutorial aid, and so on. Therefore we felt confident that the young adults (n=48) who came for the face-to-face assessment were representative of the children with "Pure-LD" who, as young adults, did not come.
- l. To analyze the academic outcomes (presence of a persistent LD) for our young adults, using their follow-up assessment data, we applied the same formulas that were used to determine LD in childhood.
- m. What were the results? How many of these young adults with a Pure LD (PLD) in childhood continued to have a persistent LD as young adults? Overall, 44% of our young adults had a persistent LD from their childhood LD. Men were more likely to continue to meet our research criteria for a "persistent" LD as a young adult (19 of the 30 young men; 63%). Among the women, 6 of the 18 (33%) continued to experience a persistent LD as

young adults. (Keep in mind that a child could have met criteria for more than one LD during childhood, and also during the follow-up young adult assessment.).

- n. What were the LDs that persisted from childhood into young adulthood?
  - n1. From the 27 participants who had a childhood RD, 8 (30%) had a persistent RD as young adults.
  - n2. Of the 25 with a childhood WLD, 12 (48%) had a persistent LD as young adults.
  - n3. There were 27 students with a childhood MLD; of these, 6 (22%) had a persistent MLD as young adults.
- o. We concluded that significant adverse academic outcomes from childhood LDs are present in many young adults, persisting even in the face of significant remedial efforts (e.g., IEPs for LD) during the school years.

## **Section VII. Recent Developments: The Birth Cohort—Early Exposure to Anesthesia During the Preschool Years**

### **Introduction.**

During the past few years, concerns have been raised about potentially adverse sequelae of anesthetic agents used with infants, toddlers and preschool children. In 2011, a multidisciplinary research team ( Anesthesiology, Epidemiology, Statistics, Psychology) studied the association between exposure to medical procedures performed under general anesthesia (before age 3) and later development of any type of LD.

These 3 studies addressed this issue:

1. Wilder RT, Flick RP, Sprung J, Katusic SK, Mickelson C, Gleich SJ, Schroeder DR, Weaver AL, Warner DO. Early exposure to anesthesia and learning disabilities in a

population-based birth cohort. *Anesthesiology* 2009;110:796-804. PMID: PMC2729550

2. Sprung J, Flick RP, Wilder RT, Katusic SK, Pike TL, Dingli M, Gleich SJ, Schroeder DR, Barbaresi WJ, Hanson AC, Warner DO. Anesthesia for cesarean delivery and learning disabilities in a population-based birth cohort. *Anesthesiology* 2009;111:302-10. PMID: PMC13076711
3. Flick R, Katusic S, Colligan R, Wilder R, Voigt R, Olson M, Sprung J, Weaver A, Schroeder D, Warner D. Cognitive and behavioral outcomes after early exposure to anesthesia and surgery. *Pediatrics* 2011;128(5):e1053-61. PMID: PMC3307194

From these studies of various exposures to general anesthesia during the preschool years, and their associations with subsequent LD, we learned

- a. It is essential to account for the severity of the medical condition for which general anesthesia was needed. This can be done, in part, by statistical and methodological procedures addressing the physiologic burden placed on the infant or toddler by the surgical or treatment procedure.
- b. Multiple exposures were associated with a 2-fold increase in the incidence of LD.
- c. A later study indicated that repeated exposure to procedures requiring general anesthesia before age 2 was also associated with increased risk for ADHD. This extended earlier findings, but using group-administered tests of cognition and achievement. The data suggested reduced efficiency in executive functioning and questions about potential injury associated with procedures requiring anesthesia, were raised.
- d. These 3 studies could not adequately address all the questions that emerged. To study them more completely, a grant from the National Institutes of Health was obtained. This

currently funds a 5-year follow-up anesthesia study. All participants are children and adolescents with varying exposures to anesthesia during the preschool years. They are completing a neuropsychological assessment battery measuring cognitive abilities, memory, executive functions and academic achievement. A unique component of this evaluation is their completion of a computer-administered set of tasks that has also been used with rhesus monkeys (and humans) in studies at the Neurotoxicology Research Center (US Food and Drug Administration). Participants will also be described by their parents using behavior checklists.

A video of the Principal Investigator, David Warner, MD, discussing these studies is available at:

<http://www.youtube.com/watch?v=7dR50tx1MAg>

\*Reprints of these publications are available upon request .

Robert C Colligan, PhD, Psychology

Slavica K Katusic, MD, Epidemiology

**History and Current Status of the *Test of Integrated Language and Literacy Skills (TILLS)*  
for Curriculum Based Assessment and Intervention  
for Integrated Oral and Written Language**

By Nicola Nelson

Nelson, N. W., Helm-Estabrooks, N., Hotz, G., & Plante, E. (2011). *Test of Integrated Language and Literacy Skills (TILLS)*, standardization version 2.0 [not for distribution but check web resources for when this becomes available]. Baltimore, MD: Paul H. Brookes Publishing Co., Inc.

The TILLS is being standardized for dual purposes: (a) differential diagnosis of oral and written language disorders and (b) informing plans about what to do next for children who are struggling with language and literacy across the age range 6;0 to 18;11. The 15 subtests (Table 1) of this Curriculum-Based Language Assessment and Intervention (Nelson, 1989; 2010) are based on a model of two language levels (sound/word and sentence/discourse) by four modalities (listening, speaking, reading, and writing). This is consistent with current research that shows that oral and written language difficulties are explained better by a language levels-by-modalities theoretical model than a receptive/expressive one (Bishop & Snowling, 2004; Catts & Kamhi, 2005; Snowling & Hayiou-Thomas, 2006; Tomblin, Zhang, Weiss, Catts, & Ellis Weismer, 2004). The language levels by modalities model predicts four diagnostic groupings, each with different implications for intervention: dyslexia (low sound/word level skills, but high sentence/discourse; listening comprehension better than reading comprehension), normal language (at least average skills in all components), oral and written language impairment (low

skills in all components), and specific comprehension impairment (high sound/word level skills and low sentence/discourse level skills across modalities). Similar profiles have been described in the literature (Catts, Hogan, & Adlof, 2005; Nation & Snowling, 2004; Scarborough, 2005; Silliman & Berninger, 2011).

Nelson, Anderson, and Applegate (2012) reported on analysis of preliminary standardization data (473 children recruited from all 9 regions of the United States) collected with support of an IES grant. A discriminant function analysis was completed on 92 cases—46 with normal language and 46 with previously diagnosed language-learning disabilities. These cases were selected as best matches according to age, sex, gender, race/ethnicity, and parental education for the students with language-learning disabilities. Overall discriminant analysis results for the preliminary data set were statistically significant (Wilks' lambda: .34098 approx.  $F(20,108) = 10.437, p < .0001$ ); sensitivity and specificity both were within target range of > 80% (83% sensitivity and 97% specificity). Variables that carried statistically significant variance in the whole group discrimination were: Vocabulary Awareness, Phonological Awareness, and Reading Fluency. Case examples were drawn from the database that illustrated the hypothesized patterns for normal language, dyslexia, and oral and written language impairment. No clear examples of specific comprehension deficit were found in the preliminary data set. The TILLS is expected to be fully standardized by 2014. Additional special population studies are underway with students with autism spectrum disorders, intellectual developmental disabilities, and deafness/hard-of-hearing.

Table 1. Subtests for Test of Integrated Language and Literacy Skills

Modality	Language Level	
	Sound/Word Level	Sentence/Discourse Level
Listening	1. Vocabulary awareness 2. Phonemic awareness	3. Story questions 6. Listening comprehension
Speaking	4. Nonword repetition	3. Story retelling 13. Social communication
Reading	10. Nonword reading 11. Reading fluency	7. Reading comprehension
Writing	5. Nonword spelling	12. Written expression
Memory	14. Digits forward 15. Digits backward	8. Following directions 9. Delayed story retelling
Nelson, N. W., Helm-Estabrooks, N., Hotz, G., & Plante, E. Developed with support of Brookes Publishing and grant R324A100354 from the U.S. Dept. of Ed., IES.		

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## **Concussions Related to Sports**

By Whitney Griffin, PhD

Sport concussion is the most frequent type of head injury that occurs in athletics (Moser et al., 2007). It can be associated with immediate symptoms of disorientation, amnesia, nausea, confusion, visual disturbance, blank stare, slurred speech, vertigo, headache, loss of consciousness, or any alteration in consciousness (Moser et al., 2007). Although loss of consciousness is the easiest to measure, it is not necessary for the diagnosis of a concussion. Furthermore, any of these symptoms may last less than 15 minutes and still indicate a mild concussion (American Academy of Neurology, 1997). As a result, student-athletes may have lingering symptoms or appear asymptomatic altogether even though there has been a change in mental status. Often, athletes refer to this phenomenon as a “ding” or “bell ringer,” (Moser et al., 2007), a harshly degrading misnomer.

In postconcussion syndrome, recovery is prolonged, and the afflicted individual continues to experience persistent symptoms, such as (a) difficulties in attention, concentration, and/or speed of mental processing; (b) emotional symptoms of irritability, depression, or moodiness; and (c) physical symptoms of headaches, fatigue, and/or sleep difficulties (Moser et al., 2007). These symptoms can all negatively impact academic and athletic performance. Recovery from concussion varies by individual and severity of concussion and management should be taken on a case-by-case basis (Escalona, Esfandiari, Broshek, & Freeman, 2010). Persistent postconcussion syndrome can manifest in problems at school with specific difficulties such as mental slowness in completing assignments, problems understanding verbal communication in group discussions, greater distractibility and poor concentration, ineffective multitasking, and severe fatigue (Moser et al., 2007). There is also evidence that athletes with multiple concussions

could have a lingering deficit in memory (Iverson, Echemendia, Lamarre, Brooks, & Gaetz, 2012). This is especially problematic for student-athletes because all of these tasks are required for them both as students and as athletes. Furthermore, because concussions cannot be “seen,” family, friends, teachers, and peers often expect concussed individuals to fully recover and “shake it off” (Moser et al., 2007). Yet, long after the injury, academic performance may greatly suffer and may be misinterpreted as laziness or attitudinal or behavioral procrastination (Moser et al., 2007). These performance issues can be injurious to student-athletes when misinterpreted by professors and coaches, especially if postconcussion syndrome is unseen and undiagnosed, which can lead to further stigmatization of academic performance for student-athletes.

### **Traumatic Brain Injuries (TBI)**

*Concussions.* Concussions are a type of traumatic brain injury (TBI). In 1997, the Center for Disease Control and Prevention (CDCP) reported that at least 300,000 athletes per year suffer concussions within the context of sports in the United States (as cited in Moser et al., 2007). However, these numbers may be grossly underestimated for two reasons. First, the CDCP based its statistics only on those athletes who lost consciousness. Second, players and coaches tend to lack awareness or minimize symptoms of concussions. Not all concussions cause a loss of consciousness. In fact, only 8.9% of the 1,003 reported injuries involved loss of consciousness, and only 27.7% involved amnesia after a second concussion (Guskiewicz, Weaver, Padua, & Garrett, 2000). Failing to self-report concussions is both extremely dangerous and horribly common. In reporting the outcome of a confidential survey of more than 1,500 high school football players regarding their concussion history, McCrea, Hammeke, Olsen, Leo & Guskiewicz (2004) noted that more than 40% believed that they were concussed but deliberately did not reveal this information for fear of losing playing time.

When assessing athletes who have recently sustained a concussion, a variety of somatic and cognitive symptoms are spontaneously reported. These symptoms often include problems with headache, dizziness, photophobia, memory, concentration, foggiess, and neuropsychological outcome (Iverson, Gaetz, Lovell & Collins, 2004). The third international conference on concussion in sport held in Zurich 2008 defined concussions as a direct or indirect force to the head that results in immediate short-lived neurologic impairment (e.g., amnesia, loss of consciousness, confusion) that resolves spontaneously, typically followed by physical, cognitive, emotional symptoms and sleep disturbance (McCrory et al., 2009).

Current evidence suggests that concussive injuries rarely result in identifiable cell death or other structural changes (Barkhoudarian, Hovda & Giza, 2011 as cited in Sady, Vaughan and Gioia, 2011). When the neural software is impaired, the brain attempts to return to its normal state, temporarily forced to use a less-efficient anabolic metabolism (Sady, Vaughan & Gioia, 2011). Cortical neurometabolic changes in the acute post-concussion phase have been found that demonstrate for the first time a correlation between subjective self-reported symptoms and objective physical changes that may be related to increased vulnerability of the concussed brain (Henry, Tremblay, Boulanger, Elleberg & Lassonde, 2010).

When assessing sports concussion, baselines and neuropsychological testing data are used to determine both the diagnosis of the injury and to track the recovery period. The baseline evaluation, which is usually conducted prior to the sport season, is not meant to represent a comprehensive assessment but is targeted to assess cognitive domains that are most often affected by concussion, such as memory, attention, speed of mental processing, and reaction time (Moser et al., 2007).

It is considered standard practice that an athlete's neurocognitive performance must return to baseline or better before returning to play, which is typically assessed and interpreted by a uniquely qualified clinical neuropsychologist. In order to conduct return to play (RTP) procedures, the athlete should first be asymptomatic at rest. Then, the athlete is progressed through increasing non-contact physical exertion until he or she has demonstrated asymptomatic status with non-contact physical exertion and non-contact sport-specific training (Moser et al., 2007). Slobounov et al. (2011) found indications of the efficacy of moderate aerobic exercise for enhancing the neural efficiency during the acute (7-10 days post-injury) and subacute (less than 3 weeks post-injury) phases of recovery from mTBI. Two available assessments are the traditional Post-Concussion Scale (Lovell et al., 2006) and the computerized Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) battery.

The neuropsychological performance of students who suffer concussions is impaired. Collins et al. (1999) found that domains of executive function, speed of information processing, speeded word fluency, and memory appeared to be attenuated in college football players with learning disability. The findings of Halterman et al. (2006) indicate that the regions of the brain associated with the orienting and executive components of visuospatial attention may be most susceptible to neural damage resulting from multiple traumatic brain injury (mTBI). Furthermore, there is evidence that athletes with multiple concussions could have a lingering deficit in memory (Iverson, Echemendia, Lamarre, Brooks, & Gaetz, 2012).

Once concussed, an athlete is at a statistically increased risk for sustaining a future concussion. Guskiewicz et al. (2003) reported that previously concussed athletes are four to six times more likely to experience a second concussion, even if the second blow is relatively mild. The same authors also found that football players with a history of three or more previous

concussions were three times more likely to sustain an incident concussion than those with no concussion history. Perhaps the most dangerous risk of sustaining a first concussion is second impact syndrome, which occurs when an athlete who sustains a head injury--often a concussion or worse injury, such as a cerebral contusion-- sustains a second head injury before symptoms associated with the first have cleared (Cantu, 1998). Following the second blow:

What happens in the next 15 seconds to several minutes sets this syndrome apart from a concussion or even a subdural hematoma. Usually within seconds to minutes of the second impact, the athlete-- conscious yet stunned--quite precipitously collapses to the ground, semicomatose with rapidly dilating pupils, loss of eye movement, and evidence of respiratory failure (Cantu, 1998, p. 38).

Second impact syndrome has significant health implications for players who do not self-report concussive symptoms and who appear asymptomatic.

It is important to note that second impact syndrome is a preventable injury if symptoms are recognized, reported, and players are sidelined to follow proper return to play protocols. In 2009, the governor of Washington signed the Zackery Lystedt Law, requiring any youth athlete suspected of sustaining a concussion be immediately removed from play and then prohibited from returning without written clearance from a licensed healthcare provider trained in concussion management. Because there was no athletic trainer or other healthcare professional at this junior high school game in 2006, it fell to the coaches to decide whether Zackery was safe to return to play. Since he had not lost consciousness after his first concussions, they decided to send him back in just fifteen minutes after he had clearly sustained a concussion. The result was a catastrophic injury due to second impact syndrome that left Zackery with irreparable brain damage and confinement to a wheelchair for the rest of his life. Even through head injuries

cannot be completely removed from sports, brain damage can be minimized if players are prevented from having rapidly successive concussions.

*Multiple traumatic brain injury (mTBI).* There is growing evidence to support the notion that individuals with asymptomatic multiple traumatic brain injury (mTBI) may have residual brain abnormalities, which may be assessed by advanced brain imaging techniques, putting these individuals at high risk for recurrent brain injuries (Slobounov et al., 2010). In a virtual reality study to understand the neural underpinning of encoded and retrieval of spatial information, Slobounov et al. (2010) found enlargements of cerebral activation in absence of encoding/retrieval deficits of the dorsolateral prefrontal cortex in asymptomatic concussed individuals, including brain reorganization and/or compensation. This finding sheds light on the neural mechanism responsible for alteration of brain functions in a clinical setting. Stuss & Benson (1986) report that damage to the frontal lobes is frequently associated with diminished self-awareness (as cited in Barkley, 2002).

*Chronic Traumatic Encephalopathy (CTE).* Chronic Traumatic Encephalopathy (CTE) is a degenerative brain disease caused by repeated head trauma (Omalu et al., 2006). The deposition of injury-related tau proteins in the brains of football players with CTE results in symptoms consistent with early onset dementia, as well as chronic neuropsychological sequelae including behavioral and personality changes and clinical depression. Two National Football League (NFL) players at ages 26 and 21 have been diagnosed with CTE post-mortem even though they had no history of concussion. These findings suggest that milder degrees of head trauma, or subconcussions, are also implicated in CTE. This raises many ethical concerns for players, coaches, parents, medical professionals, and fans alike.

As of December 2012, thirty-three former NFL players have been diagnosed post-mortem with CTE. Owen Thomas, a junior lineman at the University of Pennsylvania who committed suicide, showed early stages of CTE at the age of 21. Nathan Stiles died after his high school homecoming football game at the age of 17, making him the youngest reported CTE case to date. The cumulative effects of years of chronic and subtle brain injuries in football players are only beginning to be appreciated, particularly since such injuries are effectively invisible and undiagnosed (Gilbert & Johnson, 2011). The question remains: How to make a dangerous and potentially lethal sport safer?

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