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Idiom comprehension deficits in relation to corpus callosum agenesis and hypoplasia in children with spina bifida meningomyelocele

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Abstract

Idioms are phrases with figurative meanings that are not directly derived from the literal meanings of the words in the phrase. Idiom comprehension varies with: *literality*, whether the idiom is literally plausible; *compositionality*, whether individual words contribute to a figurative meaning; and *contextual bias*. We studied idiom comprehension in children with spina bifida meningomyelocele (SBM), a neurodevelopmental disorder associated with problems in discourse comprehension and agenesis and hypoplasia of the corpus callosum. Compared to age peers, children with SBM understood decomposable idioms (which are processed more like literal language) but not non-decomposable idioms (which require contextual analyses for acquisition). The impairment in non-decomposable idioms was related to congenital agenesis of the corpus callosum, which suggests that the consequences of impaired interhemispheric communication, whether congenital or acquired in adulthood, are borne more by configurational than by compositional language.

Keywords: Idioms; Corpus callosum; Spina bifida meningomyelocele; Hydrocephalus; Language deficits; MRI

1. Introduction

Idioms are non-literal phrases (e.g., *kick the bucket*) whose figurative meanings (here, *to die*) cannot readily be derived from the literal meanings of their individual words (here, *kick* and *bucket*). Adult native language speakers have a broad repertoire of idioms. Children, however, only gradually acquire mastery of idioms. Developmental studies have shown that very young children interpret idioms literally and use lexical and morphosyntactic decoding skills to derive literal meanings (Levorato, 1993). As they develop further, children begin to understand the figurative meanings of idioms (Ackerman, 1982; Cacciari & Levorato, 1989; Douglas & Peel, 1979; Gibbs, 1987, 1991; Kempler, Van Lancker, Marchman, & Bates, 1999; Levorato & Cacciari, 1995; Lodge & Leach, 1975; Nippold & Tarrant Martin, 1989; Prinz, 1983).

Idioms are not equally understandable, and ease of comprehension varies with: *literality*, the extent to which the idiom is literally plausible; *compositionality*, the extent to which the meanings of individual words in the idiom contribute to its figurative meaning; and the presence of *contextual bias*. These three factors operate during acquisition as well as during adult function (Cacciari & Levorato, 1989; Gibbs, 1991; Gibbs, Nayak, & Cutting, 1989; Kemper, 1986; Levorato, 1993; Titone & Connine, 1994a, 1994b).

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In this paper, the terms decomposable and non-decomposable are used to refer to idioms at different ends of a compositionality spectrum, although these words are somewhat isomorphic with terms such as analyzable and non-analyzable, or transparent and opaque. In decomposable idioms, the individual lexical items contribute to the figurative meaning (e.g., the words in *talk a mile a minute* connote speech rate), whereas in non-decomposable idioms (e.g., *kick the bucket*), the words provide limited clues to meaning (Gibbs et al., 1989; Titone & Connine, 1994a). Compositionality interacts with context. Decomposable idioms are acquired in a relatively *context-independent* manner, whereas non-decomposable idioms, being less syntactically and lexically flexible, are relatively *context-dependent*. Decomposable and non-decomposable idioms appear to engage partially distinct processes in the course of development (Huber-Okrainec, 2002), the evidence being 3-fold. Age-related improvements in comprehension are more marked for non-decomposable than for decomposable idioms. Children are better at understanding decomposable idioms than non-decomposable idioms without a biasing linguistic context (Gibbs, 1991; Gibbs & Nayak, 1989). During acquisition, young children appear to approach idiom comprehension with the tools they use to understand literal language, by applying a compositional approach (Levorato, 1993). The result is that they understand decomposable idioms (analyzed more like literal language) more readily than non-decomposable idioms (Gibbs, 1991). Comprehension of both types of idiom improves throughout the school-age years, although development involves a shift from better comprehension of decomposable than non-decomposable idioms in the early school years, to the opposite pattern in the mid- to late school-age years, suggesting that learned, non-decomposable idioms may involve fewer processing demands than learned, decomposable idioms requiring compositional analysis (Huber-Okrainec, 2002).

For a given idiom, figurative and literal meanings may co-exist, especially in childhood acquisition. If, as suggested (Bobrow & Bell, 1973), activation of the literal meaning is stronger and more rapid than the activation of the figurative meaning, then the literal meaning must be suppressed to maintain a figurative interpretation. Young children make literal interpretation errors on idioms (Lodge & Leach, 1975). It is therefore not surprising that the extent to which an idiom is literally plausible (*literality*) has considerable influence over idiom acquisition and comprehension in childhood (Huber-Okrainec, 2002). Young children with incomplete mastery of idioms have particular difficulty with idioms whose meanings are highly literal, suggesting incompletely developed suppression of the literal meaning.

In addition to the perspectives afforded by studies of idiom comprehension in adult function and typical development, studies have emerged providing insight into the brain bases of figurative language disorders. Figurative language impairments exist in a range of brain disorders; a distributed neural system is involved in idiom comprehension; both the right and the left hemisphere contribute to figurative language comprehension; and interhemispheric integration is required for successful idiom comprehension.

Figurative language impairments have been reported in individuals with a wide variety of brain-based disorders, including those with right hemisphere brain damage (e.g., Brownell, Simpson, Bihrle, Potter, & Gardner, 1990; Critchley, 1991; Foldi, Cicone, & Gardner, 1983; Gagnon, Goulet, Giroux, & Joanette, 2003; Giora, Zaidel, Soroker, Batori, & Kasher, 2000; Joanette, Goulet, & Hannequin, 1990; Kempler et al., 1999; Mackenzie, Begg, Brady, & Lees, 1997; Myers & Linebaugh, 1981; Tompkins, Boada, & McGarry, 1992; Van Lancker & Kempler, 1987; Weylman, Brownell, Roman, & Gardner, 1989; Winner & Gardner, 1977), left hemisphere brain damage (Gagnon et al., 2003; Tompkins et al., 1992), frontal lobe disease (Benton, 1968), agenesis of the corpus callosum (Paul, Van Lancker-Sidtis, Schieffer, Dietrich, & Brown, 2003), Alzheimer's disease (Kempler, Van Lancker, & Read, 1988; Papagno, Lucchelli, Muggia, & Rizzo, 2003), Down syndrome (Papagno & Vallar, 2001), childhood closed head injury (Dennis & Barnes, 1990), and congenital mental retardation (Ezell & Goldstein, 1991). Idiom comprehension deficits have also been observed in children with more general, behaviorally defined, cognitive and learning impairments, such as Language/Learning-Disability (Secord & Wiig, 1993).

The diversity of idiom impairments, both with respect to clinical condition and neural bases, is consistent with recent evidence that figurative language processing is not restricted to a single brain region, but, instead, is represented in distributed neural networks (Gagnon et al., 2003; Papagno, 2001). The brain basis for the distributed neural system involved in idiom and metaphor comprehension is not fully established, although it appears to include contributions from each hemisphere, as well as interhemispheric integration (Burgess & Chiarello, 1996; Faust & Weisper, 2000; Paul et al., 2003).

The right hemisphere is important for making inferences and contributes to discourse processes integrating context, world knowledge, pragmatic and figurative language (including idioms) (Brownell, Potter, Bihrle, & Gardner, 1986; Brownell et al., 1990; Bryan & Hale, 2001; Burgess & Chiarello, 1996; Critchley, 1991; Giora et al., 2000; Joanette et al., 1990; Kempler et al., 1999; Mackenzie et al., 1997; Molloy, Brownell, & Gardner, 1990; Myers & Linebaugh, 1981; Paradis, 1998; Van Lancker & Kempler, 1987; Winner & Gardner, 1977). Although idiom comprehension deficits have been observed in adults with both left and right cerebral lesions (Gagnon et al., 2003; Tompkins et al., 1992), the two hemispheres may make somewhat different contributions to idiom comprehension. Adults with right hemisphere lesions have particular difficulty in using context to understand figurative meanings and make inferences (Brownell et al., 1986; Foldi et al., 1983; Van Lancker & Kempler, 1987), and in suppressing contextually inconsistent meanings (Tompkins, Baumgaertner, Lehman, & Fassbinder, 2000). Integrating figurative phrases in discourse within the context of the overall literal message likely involves both hemispheres for comprehension, with each hemisphere making a distinct contribution (Burgess & Chiarello, 1996).

Communication between the two hemispheres is particularly important when multiple meanings need to be accessed for a phrase: the right hemisphere is important for making context-appropriate inferences and reinterpreting a phrase when the left has chosen an irrelevant meaning (Beeman, 1993). Functional evidence for a hemispheric integration model of discourse is that both hemispheres process contextually relevant semantic information for discourse comprehension, while propositional information is only processed in the left hemisphere (Long & Baynes, 2002). Neural evidence also suggests interhemispheric integration. In normal individuals, one study has shown that comprehension of literal sentences activates the parietal cortex, the precuneus, the middle and inferior temporal gyri and temporal pole, and the prefrontal and basal frontal cortex of the left hemisphere. Comprehension of figurative language activates approximately the same areas in the left hemisphere along with the posterior cingulate, the precuneus, the middle temporal gyrus, and the prefrontal cortex in the right hemisphere (Bottini et al., 1994). However, it is noted that much of the literature on literal, phonological, and lexical aspects of language have shown similar results, leaving unresolved questions regarding the extent of neural hemispheric integration in literal compared to figurative language.

If figurative word meanings are represented in the right hemisphere, and are accessed by the left hemisphere for sentence-level processing, then interhemispheric communication is likely important for successful metaphor (Faust & Weisper, 2000) and idiom comprehension. The corpus callosum appears to be part of this mechanism (Paul et al., 2003).

The corpus callosum has been implicated in interhemispheric transfer, in general, and transfer of language information, in particular. Evidence from a case report following a staged callosal section suggests that the anterior portion of the corpus callosum is important for transfer of higher cognitive and semantic language functions (Sidtis, Volpe, Holtzman, Wilson, & Gazzaniga, 1981). The central portion or body of the corpus callosum and the splenium, which connects the temporal, parietal, and occipital lobes (Klaas, Hannay, Caroselli, & Fletcher, 1999), are also likely important for interhemispheric transfer of language information (Funnell, Corballis, & Gazzaniga, 2000; Gazzaniga, Kutas, Van Petten, & Fendrich, 1989). Excitatory cellular interhemispheric corpus callosal connections may correspond to words (Mohr, Pulvermuller, Rayman, & Zaidel, 1994; Mohr, Pulvermuller, & Zaidel, 1994). Language processing is more proficient when both hemispheres have access to lexical information, and comprehension is better when words are presented to both, rather than one, visual half fields (Berger, 1988; Mohr, Pulvermuller, et al., 1994; Mohr et al., 1994), an effect missing when the corpus callosum is sectioned (Mohr, Pulvermuller, et al., 1994). Split-callosum patients with spared splenium fibers do not show transfer of color, shape or size information, although they can transfer word and rhyme word information, suggesting some functional specificity of the corpus callosum for language transfer (Funnell et al., 2000; Gazzaniga et al., 1989).

The corpus callosum begins to form between seven to twelve weeks of gestation and is generally formed by 20 weeks, although it continues to develop throughout gestation and into post-natal life (Barkovich, 1994; Barkovich & Norman, 1988). Development occurs in the following sequence: the genu forms first, followed by the body, which is followed by the splenium, and the rostrum is formed last, between 18 and 20 weeks of gestational age (Barkovich & Norman, 1988). Corpus callosum agenesis occurs because of abnormal neuronal migration to any or all of the regions of the corpus callosum (Barkovich, 1994). Agenesis of the corpus callosum occurs because the axons of callosal neurons develop in parallel to the interhemispheric fissures, rather than connecting areas in the two cerebral hemispheres (Barkovich, 1994). As a result, agenesis of the corpus callosum disrupts normal functional connections (Quigley et al., 2001), including those important for language transfer. Deficits in interhemispheric transfer have been hypothesized to be part of the neuropathogenesis associated with childhood developmental language disorder (Fabbro, Libera, & Tavano, 2002).

Congenital anomalies of the corpus callosum affect language, and callosal agenesis is associated with deficits in idiomatic, figurative, and syntactic–pragmatic language (Dennis, 1981; Paul et al., 2003; Quigley et al., 2001). Cases of callosal agenesis are typically identified on a sporadic basis, often from adventitious clinical findings. However, in one neurodevelopmental disorder, spina bifida meningomyelocele (SBM), callosal agenesis and hypoplasia are common.

SBM is a common congenital brain-based neurodevelopmental disorder (0.5–1.0 per 1000 live births, Fletcher, Dennis, & Northrup, 2000; Charney, 1992) caused by incomplete neural tube closure during the first 5–6 weeks of gestation and resulting in abnormal function and maturation of both the spinal cord and brain (Barkovich, 1990; Brocklehurst, 1976; Charney, 1992).

SBM is associated with profound disturbances of brain development that include abnormal formation and maturation of the posterior cortex and white matter, midbrain, cerebellum, and corpus callosum (Dennis et al., 1981; Fletcher et al., 1992, 2000; Hannay, 2000). SBM is of considerable interest to the study of the neurobiology of idiom comprehension, not only because many children with SBM have agenesis and/or hypoplasia of the corpus callosum, but also because they have deficits in several language skills likely to be important for idiom comprehension.

The corpus callosum is compromised due to primary agenesis of callosal structures during embryogenesis and because of hypoplastic development secondary to increased intracranial pressure and hydrocephalus. Hydrocephalus develops in approximately 80–90% of children born with SBM (Reigel & Rothstein, 1994). SBM is associated with corpus callosum malformations, most commonly in the posterior regions (Hannay, 2000), which are important for interhemispheric transfer (Klaas et al., 1999). Hypoplasia and agenesis of the corpus callosum disrupt the integration of information between the hemispheres (Hannay, 2000; Klaas et al., 1999). The extent of corpus callosum dysmorphology varies in children with SBM. While some children with SBM have an intact but hypoplastic corpus callosum, others have corpus callosum hypoplasia or agenesis as part of the primary neuroanatomical malformations associated with their disorder (Hannay, 2000).

Children with SBM exhibit a distinct set of core language processing deficits. These include relative preservation of basic language processes and relative impairment of context-dependent language (Barnes & Dennis, 1998; Dennis & Barnes, 1993; Dennis, Hendrick, Hoffman, & Humphreys, 1987; Dennis, Jacennik, & Barnes, 1994; Fletcher, Barnes, & Dennis, 2002).

Many basic, structural language and single-word skills are intact in children with SBM, including picture vocabulary and grammar (Brookshire et al., 1995; Byrne, Abbeduto, & Brooks, 1990; Dennis et al., 1987; Parsons, 1986; Schwartz, 1974; see review by Fletcher et al., 2002). Children with SBM can produce narratives with the same number of words as controls (Dennis et al., 1994; Huber-Okrainec, Dennis, Brettschneider, & Spiegler, 2002).

Children with SBM have impairments in processes important for meaning construction in discourse, including several processes important for idiom comprehension. Their specific impairments are in discourse coherence, inferencing, suppressing contextually irrelevant meaning, and deriving meaning from context (Barnes & Dennis, 1998; Dennis & Barnes, 1993; Dennis et al., 1987; Dennis et al., 1994; Fletcher et al., 2002).

Content-poor discourse (Dennis et al., 1987; Hadenius, Hagberg, Hyttnes-Bensch, & Sjorgen, 1962; Taylor, 1961; Tew, 1979) has been observed in children with SBM with average intelligence. They have poor discourse coherence, impoverished semantic content, and difficulty in deriving the gist of discourse (Barnes & Dennis, 1998; Dennis & Barnes, 1993; Dennis et al., 1987; Dennis et al., 1994; Fletcher et al., 2002).

Children with SBM, even those with average or higher verbal IQs have more difficulty than their peers in making inferences (Barnes & Dennis, 1998; Dennis & Barnes, 1993), even when they have the requisite knowledge (Barnes & Dennis, 1998). Inferencing may be part of the mechanism by which the words in an idiom are integrated with context to establish a figurative rather than a literal meaning.

Children with SBM have selective difficulty with meaning suppression. They can activate word meanings, but are less able than typically developing peers to suppress contextually irrelevant meanings (Barnes, Faulkner, Wilkinson, & Dennis, 2004). This suppression deficit may limit comprehension of idioms whose meanings are literally plausible and for which literal suppression is required.

Children with SBM are a population in which to address a number of questions about the behavioral and brain bases of idiom comprehension. Children with hydrocephalus of average intelligence, including children with SBM, do not optimize the use of context to derive meaning for novel, context-dependent, similes (Barnes & Dennis, 1998), even though they can understand familiar figurative phrases (Dennis & Barnes, 1993). Comparison of decomposable and non-decomposable idioms in children with the particular language deficits of children with SBM would add to the information about language comprehension in this disorder, and also inform developmental and adult models of figurative language comprehension. Understanding how the typical course of figurative language development can be altered by specific congenital brain malformations of the corpus callosum would contribute to emerging models of interhemispheric integration in figurative language comprehension.

We studied idiom comprehension in children with SBM in relation to two questions. The first question concerned idiom comprehension in relation to literality, compositionality, and contextual bias, and the second concerned brain–behavior relations.

- Do children with SBM understand idioms as well as their age peers and does the form of idiom influence comprehension? We hypothesized that children with SBM would have more comprehension problems for non-decomposable, context-reliant idioms than for decomposable idioms, which allow use of some of the analytic tools of literal language, regardless of context. We also hypothesized that children with SBM would have more difficulty with highly literal idioms than low literal idioms, due to poor suppression mechanisms.

- Is performance related to the neuroanatomical status of the corpus callosum in children with SBM? If inter-hemisphere integration is important for idiom comprehension, then children with abnormal development of the corpus callosum, such as those with SBM, should be impaired on idiom comprehension tasks. We predicted, specifically, that children with SBM and with agenesis of the splenium only (or splenium, body and rostrum) of the corpus callosum would be more impaired than those with callosal hypoplasia, who would be more impaired than children with SBM with an intact corpus callosum. We hypothesized that idiom comprehension deficits would be marked in children with SBM with agenesis particularly for non-decomposable idioms, which require integration of contextual information from discourse for acquisition, and for high literal idioms, because developmental between-hemisphere corpus callosum inhibition (Dennis, 1976) is required to suppress competition between literal and figurative meanings.

2. Method

2.1. Participants

Participants were 76 first-language English-speaking children assigned to one of two groups based on clinical condition: children with SBM ($n = 38$; mean age in years 12.97(SD, 3.06); age range 7.25–18.67 years) and typically developing age- and gender-matched child controls ($n = 38$; mean age in years 12.87(SD, 2.91); age range 7.33–17.83 years). Participants with SBM had been born with the condition and treated for hydrocephalus with a diversionary shunt shortly after birth. The typically developing participants in the control group met the following exclusion criteria: diagnosis of a language disorder; requirement for special educational services; schooling in a language other than English; chronic disorder (e.g., diabetes); history of premature birth or low birth weight (e.g., birth weight < 2500 g/5 lbs., and/or <37 weeks gestation); and history of hospitalization or medical attention for a closed head injury. This study was reviewed and approved by the board of ethics at the Hospital for Sick Children and the research committee at the Hamilton–Wentworth Catholic District School Board. All children were voluntary participants, and gave informed assent or consent depending on their age.

Inclusion in the study required all participants to have achieved a Verbal Intelligence Quotient (VIQ) score of 70 or above on a standard intelligence test: for children with SBM, the Stanford–Binet Intelligence Scale-Fourth Edition was used (the Vocabulary subtest of Verbal Reasoning, and the Pattern Analysis subtest of Abstract Visual Reasoning) (Thorndike, Hagen, & Sattler, 1986); for child controls, the Wechsler Abbreviated Scale of Intelligence was used (Vocabulary and Matrix Reasoning subtests) (Wechsler, 1999).

Table 1
Sample characteristics

Condition	SBM	Control
Sample size	($n = 38$)	($n = 38$)
Age at test (Years)	12.97(3.06)	12.87(2.91)
Age range (Years)	7.25–18.67	7.33–17.83
Gender distribution (M:F)	(16:22)	(17:21)
Total IQ (standard score)	88.97(13.97)	103.84(10.12)
Verbal IQ (percentile)	46.92(26.60)	63.74(20.35)
Verbal IQ	98.42(13.39)	—
Verbal IQ range	74–126	—
Handedness (R:L)	(25:13)	—
Site of shunt insertion (RH:LH:Bilateral)	(23:12:2)	—

Note. Values in table are means (*SD*).

Demographic and IQ information are in Table 1.

2.2. Magnetic resonance imaging acquisition and analyses

Thirty-seven children with SBM had magnetic resonance imaging (MRI) scans that were analyzed for patterns of corpus callosum dysmorphology, particularly with respect to the intactness of the splenium, body, rostrum, and genu. The cerebellum was also analyzed. MRI scans were obtained using a Siemens scanner at the Hospital for Sick Children.

2.2.1. Corpus callosum

A series of the sagittal plane representing spin echo T1-weighted sagittal localizers, FOV 24, TR 500, TE 14 256×192 matrix, 3 mm skill 0.3, 2 repetitions were taken. The midsagittal slice of this series was used for the analysis of the corpus callosum in this study. The midsagittal T1-weighted MRI scans were read by an experienced pediatric neuroradiologist. The rostrum, genu, body, and splenium of the corpus callosum were qualitatively analyzed as normal, hypoplastic, or agenetic.

The parts of the corpus callosum develop over time in a fixed order, with the timing of gestational insult producing different patterns of agenesis and hypoplasia (Barkovich, 1994). Children with SBM with varying degrees of corpus callosum dysmorphology and hypoplasia were compared based primarily on the intactness of the splenium and body, and group comparisons corresponded roughly to hypothesized timing of gestational insult (Barkovich, 1994; Hannay, 2000).

Four subgroups were identified. The ***agenesis*** subgroup ($N = 8$) had agenesis of the splenium (i.e., complete absence of transcallosal fibers) and agenesis or hypoplasia of the body, an absent or hypoplastic rostrum, and a present or hypoplastic genu, a pattern suggesting that the insult was early and disrupted development for an extended period of time, well past the first trimester (Hannay, 2000). The ***hypoplastic*** subgroup ($N = 10$) had a hypoplastic splenium and body (i.e., some but not a normal number of existing transcallosal fibers), a rostrum that was either absent, hypoplastic or present, and a genu that was hypoplastic or present, a pattern suggesting less prolonged or less disrupted neuroembryological development. The ***intact*** subgroup ($N = 8$) had a corpus callosum that was largely intact, and included the splenium and/or body with the rostrum and genu being present, a pattern suggesting that the insult occurred later than both of the first two groups (i.e., after the genu had developed) and was not as prolonged (i.e., did not disrupt development of the rostrum, the last part of the corpus callosum to develop). The ***control*** subgroup ($N = 11$) was composed of typically developing child participants. Examples of MRI scans from each group are shown in Fig. 1.

The test ages of the four subgroups did not differ. All participants had a VIQ score above 70. Although VIQ between the four groups did not differ significantly, children with SBM had lower mean scores than did the controls. However, children with SBM were all within the normal IQ range and exhibited verbal intelligence strengths in their overall profile of abilities. Subgroup demographic and IQ information are in Table 2.

2.2.2. Cerebellum

To determine whether idiom comprehension deficits are specifically related to corpus callosum dysmorphology, and not to widespread brain dysmorphology, we examined the relation between idiom comprehension and the cerebellum. Because the cerebellum has no theoretical relationship to idioms, we hypothesized no relation with cerebellar dysmorphology. Qualitative analyses of the cerebellum were obtained from the coronal, sagittal, and axial slices. The MRI data of the cerebellum were read by an experienced pediatric neuroradiologist and coded on two measures: (1) dysplastic or normal; and (2) small or normal.

2.3. Procedure

The experimental tasks were programmed using MacStim Macintosh software (Darby, 2000).

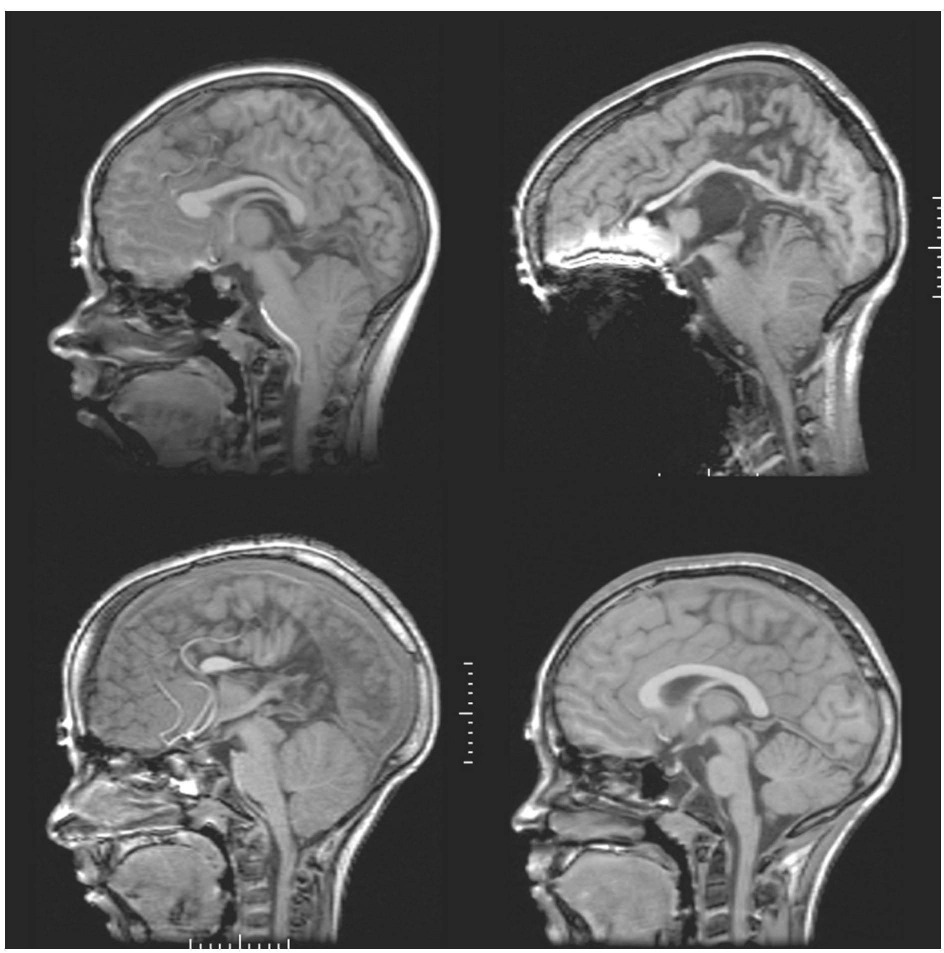

Fig. 1. (Top left) Mid-sagittal T1 weighted MRI of a child with SBM showing an ***intact*** corpus callosum. (Top right) Mid-sagittal T1 weighted MRI of a child with SBM showing ***hypoplasia*** of the corpus callosum. (Bottom left) Mid-sagittal T1 weighted MRI of a child with SBM with ***agenesis*** of the rostrum, body and splenium of the corpus callosum. (Bottom right) Mid-sagittal T1 weighted MRI of normal corpus callosum in a typically developing 12-year-old ***control***.

Table 2
Sample characteristics

Corpus callosum	Partial agenesis	Hypoplastic	Intact	Control
Sample size	(*n* = 8)	(*n* = 10)	(*n* = 8)	(*n* = 11)
Age at test (Years)	12.98 (2.48)	14.38 (3.29)	13.72 (3.11)	13.72 (2.82)
Age range (Years)	9.75–15.50	8.17–18.67	9.75–17.17	9.58–17.17
Gender distribution (M:F)	3:5	2:8	5:3	4:7
Total IQ (standard score)	93.25 (10.79)	94.20 (18.72)	91.88 (10.72)	108.55 (10.72)
IQ range	76–110	63–111	74–103	85–121
Verbal IQ (percentile)	52.75 (24.79)	58.60 (31.56)	48.75 (22.10)	69.00 (20.27)

Note. Values in table are mean (*SD*).

2.3.1. Pre-training

Each participant was trained to listen to a simple pre-recorded literal sentence presented on a computer, while looking at a blank computer screen. Immediately after hearing the sentence, a black dot appeared in the center of the screen, to signal that the picture stimulus was about to appear, immediately followed by a picture which either represented, or was inconsistent with, the meaning of the sentence. The children were trained to respond by pushing a *yes* button if the picture represented the meaning of the sentence, and a *no* button if it did not.

2.3.2. Choice reaction time test

A 10-trial choice reaction time test prior to testing provided a baseline response time measure to serve as a control for individual differences in reaction time (including both motor response and slow cognitive processing abilities) between children with SBM and controls. We considered it important to have a measure of processing time and motor response to use as a covariate when comparing response times between children with SBM, who have some processing speed limitations (Dennis, Hetherington, Spiegler, & Barnes, 1999; Hetherington & Dennis, 1999), and controls. The choice reaction time task involved deciding whether a picture represented a declarative sentence or not. This task had similar requirements to the idiom task (i.e., listening to a phrase, processing a picture representation, making a choice, and responding by pushing a button) and could be used as a covariate in comparing idiom processing in the two groups. Accuracy and response time were measured for the choice reaction time test. There were five correctly matched sentence-picture items and five incorrectly matched sentence-picture items requiring five *yes* and five *no* responses.

2.3.3. Idioms

In the Titone and Connine (1994a) study, 226 undergraduate students had rated idiomatic phrases on dimensions of:

- *Familiarity* (how frequently an idiom was encountered in any type of discourse, rated on a 7-point scale where 1 was "never heard before" and 7 was "very frequently encountered").
- *Meaningfulness* (how understandable the meaning was, rated on a 7-point scale where 1 was "not meaningful at all" and 7 was "very meaningful").
- *Literality* (potential for a literal interpretation, rated on a 7-point scale where 1 "did not have a possible literal interpretation" and 7 "definitely had a plausible literal interpretation").
- *Compositionality* (the extent to which the literal meanings of the parts contribute to the overall figurative interpretation of the idiom, rated as either decomposable or non-decomposable).

There are no available ratings on these dimensions by school-age children. Child rather than adult ratings might also be useful for the study of idiom development (Nippold & Taylor, 2002).

Forty-eight of the Titone and Connine (1994a) idioms and their ratings on familiarity, literality, and compositionality were used. All 48 idioms were highly familiar (very frequently encountered, range 4.6–6.4 and very meaningful, range 5.48–6.98). We used highly familiar, meaningful idioms to examine how children process and acquire commonly used idioms that vary on dimensions of literality and compositionality. The rationale for selecting a restricted range of highly familiar idioms was to ensure that the groups of idiomatic stimuli (non-decomposable compared to decomposable; highly literal compared to low literal) would be equal with respect to the degree of *familiarity*. While the idiomatic stimuli varied somewhat within this restricted range, degree of *familiarity* did not statistically differ between groups of idiomatic stimuli in this study. In this sense, we controlled for the possibility of *familiarity* acting as a confounding variable within our findings.

Idioms with mean literality rating scores of 1–3 (Titone & Connine, 1994a) were classified as low literal (range 1.78–3.82, e.g., *be on cloud nine*) and those with ratings of 4–6 as highly literal (range 4.07–6.56, e.g., *a piece of cake*). Based on mean compositionality ratings (Titone & Connine, 1994a), idioms were grouped as non-decomposable (mean percent rated as non-decomposable, range 60.71–100.00, e.g., *kick the bucket*) and decomposable (mean percent rated as decomposable, range 0.00–48.15, e.g., *talk a mile a minute*).

The literality and compositionality dimensions of idioms vary continuously, not categorically, although, for purposes of the study we have treated these dimensions as categorical by selecting idioms at each end of the two spectra. We recognize that idioms are not fixed phenomena, that many idioms cannot be unambiguously characterized as either decomposable or non-decomposable, that analytic processes do operate on non-decomposable idioms (Van Lancker Sidtis, 2004), and that formulaic language including idioms may occur in an altered form (Nicolas, 1995).

The 48 test idioms and Titone and Connine (1994a) ratings are listed in the Appendix.

2.3.4. Picture stimuli

For each of the 48 idioms, an artist drew two pictures, one representing the figurative (non-literal) meaning of the phrase, the other representing the literal meaning of the phrase (see Fig. 2 for an example). Pictures rather than words were selected because of varying degrees of age and hence literacy in the children tested; pictures are commonly used in developmental comprehension studies (e.g., Abkarian, Jones, & West, 1992; Brinton, Fujiki, & Mackey, 1985; Kempler et al., 1999; Lodge & Leach, 1975). The pictures were drawn to represent the idioms varying in both compositionality and literality. It is noted that the pictoral representations, like the verbal representations of idioms, varied in *literality* (the extent to which they are literally plausible). We tested children's comprehension of idioms that varied in degree of *literality* (how plausible an idiom is) and *compositionality* on a paired picture to verbal idiom matching task.

2.3.5. Idiom stimuli test presentation

Each child was tested on all 48 idioms. Half of the idioms were presented in an isolated sentence (e.g., "Shelly *hit the sack*.") presented verbally; the other half were presented with a contextual sentence (of simple declarative form) presented verbally that biased the figurative interpretation (e.g., "Shelly had a long day. Shelly *hit the sack*."). Each child was given one of four stimulus sets, containing all 48 idioms presented in different conditions (i.e., one quarter of each of the idioms was presented in context followed by a figurative picture, and one quarter followed by a literal picture, and one quarter of each of the idioms was presented in isolation followed by a figurative picture, and one quarter followed by a literal picture). Within each stimulus set, presentation of each of the idioms was randomized.

The idioms represented different levels of compositionality (non-decomposable vs. decomposable) and degree of literality (high literal vs. low literal). To

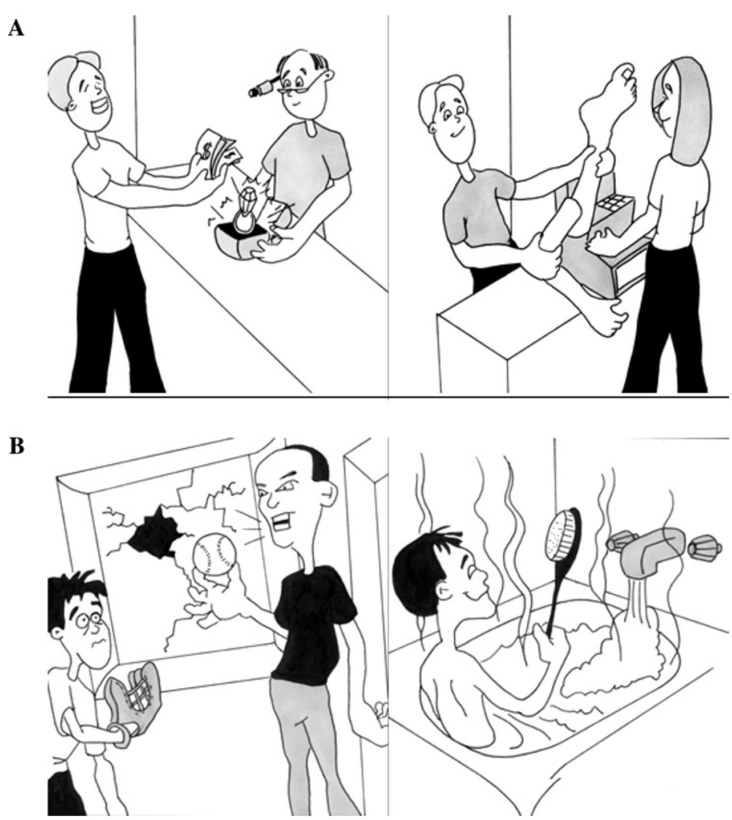

Fig. 2. (A) Picture stimuli for "*It cost and arm and a leg*." Figurative interpretation (left) and literal interpretation (right). (B) Picture stimuli for "*In hot water*." Figurative interpretation (left) and literal interpretation (right).

analyze how compositionality influences speed and accuracy, literality must be controlled for (i.e., equal numbers of high literal and low literal idioms should be in each group of non-decomposable and decomposable idioms). In the same way, to analyze literality, compositionality must be controlled for (i.e., equal numbers of non-decomposable and decomposable idioms should be in each group of high literal and low literal idioms). By doing this, two separate analyses, one for the effects of compositionality and one for the effects of literality, could be conducted.

2.3.6. Testing period

The format of the testing period was analogous to the *pre-training*. Each child heard pre-recorded verbal presentations of the 48 idioms, either in isolation or preceded by a sentence biasing the figurative meaning. Idioms were presented one at a time, with each being immediately followed first by a black dot in the center of the lap top computer screen, and then by a visual presentation of one of the two pictures (figurative or literal). For each idiom, the children and adolescents responded by pressing a *yes* or *no* button as fast as they could to indicate whether the picture represented the idiom. Accuracy and response time were measured.

3. Results

The data were analyzed using Statistical Package for Social Sciences (SPSS) 10.1 software. An α level of .05 was used for all statistical tests. Tukey's Honestly Significant Difference (HSD) test was used for post hoc analyses of significant effects.

Mean response time for correct *yes* responses from the choice reaction time test was used as a covariate when analyzing responses that accepted the figurative interpretation, and mean response time for correct *no* responses from the choice reaction time test was used as a covariate when analyzing responses that rejected the literal interpretation for all analyses of comprehension speed (i.e., ANCOVA and MANCOVA models).

3.1. Idiom comprehension in children with SBM

In comparing idiom comprehension in children with SBM and controls, we hypothesized differences in both accuracy and speed. We thought that children with SBM would access figurative interpretations, but would be less able than controls to reject the literal interpretation of idioms, because of their deficits in suppressing contextually irrelevant meaning, using context to derive meaning, and integrating context to make discourse cohesive (Barnes & Dennis, 1998; Barnes et al., 2004; Fletcher et al., 2002). We hypothesized that children with SBM would show slower comprehension of idioms, as they do with some other aspects of language (Dennis et al., 1987; Huber-Okrainec et al., 2002).

Interpreting idioms requires that the figurative interpretation be accepted and the literal interpretation be rejected. ANOVA (accuracy) and ANCOVA (speed) models were used to test between group differences for: accepting the figurative interpretation and rejecting the literal interpretation of non-decomposable idioms in isolation and in context, and accepting the figurative interpretation and rejecting the literal interpretation of decomposable idioms in isolation and in context.

A summary of the results reported in the text for the effects of literality and compositionality on all tasks is presented in Table 3. Performance on the idiom comprehension task was not related to handedness or site of shunt insertion in children with SBM.

3.1.1. Effects of compositionality

In studying how compositionality affects idiom comprehension in the SBM and control groups, we hypothesized that children with SBM, first, would show deficits on non-decomposable, context-dependent idioms, because of their difficulties making inferences and deriving meaning from linguistic context (Barnes & Dennis, 1998; Dennis & Barnes, 1993), and second, would be less impaired on decomposable idioms, for which they possess the requisite literal analytic tools (Dennis et al., 1987; Fletcher et al., 2002). With younger typically developing children, decomposability facilitates comprehension in children who have not acquired full representations of idiomatic meanings (Gibbs, 1991).

In considering whether a supportive context facilitates idiom comprehension, we hypothesized that children with SBM would be, first, less adept at using context to guide comprehension, and, second, less accurate on idioms presented in isolation, especially non-decomposable, context-reliant idioms.

3.1.1.1. Accuracy. ANOVA models revealed that children with SBM performed significantly less accurately than controls in accepting the figurative interpretation of non-decomposable idioms presented in isolation $F(1,74)=7.49$, $p=.008$ and in rejecting the literal interpretation of idioms regardless of compositionality or linguistic context; non-decomposable idioms in isolation $F(1,74)=14.92$, $p=.000$, and in context $F(1,74)=9.82$, $p=.002$, decomposable idioms in isolation $F(1,74)=8.27$, $p=.005$ and in context $F(1,74)=6.89$, $p=.011$.

3.1.1.2. Speed. ANCOVA models revealed that children with SBM were significantly slower than controls to accept the figurative interpretation of non-decomposable idioms presented in isolation $F(1,72)=7.91$, $p=.006$ and in context $F(1,72)=7.19$, $p=.009$ and of decomposable idioms

Table 3
Mean accuracy (percent correct) and speed (ms) of idiom comprehension

	Accuracy		Speed	
	SBM	Control	SBM	Control
Compositionality				
Accept the figurative interpretation of				
Non-decomposable idioms in isolation	69.29(24.36)[a]	83.33(20.13)	2925.82(1450.29)[a]	1783.08(952.60)
Decomposable idioms in isolation	68.42(25.93)	75.44(20.04)	3078.50(1343.50)[a]	2064.09(1024.23)
Non-decomposable idioms in context	84.65(19.90)	89.91(12.58)	2886.39(1378.16)[a]	1823.63(928.52)
Decomposable idioms in context	75.00(25.33)	82.46(15.47)	3297.25(1523.50)[a]	2087.92(982.39)
Reject the literal interpretation of				
Non-decomposable idioms in isolation	65.79(32.18)[a]	88.16(15.46)	2321.25(1299.99)	1552.07(912.97)
Decomposable idioms in isolation	67.98(33.19)[a]	85.96(19.58)	2662.72(1184.25)	1710.09(954.88)
Non-decomposable idioms in context	75.00(31.89)[a]	92.98(15.32)	2354.07(1172.28)[a]	1406.44(702.27)
Decomposable idioms in context	71.93(30.54)[a]	86.40(14.93)	2695.29(1229.68)	1783.62(919.27)
Literality				
Accept the figurative interpretation of				
High literal idioms in isolation	65.79(25.10)[a]	77.19(19.92)	3146.71(1718.53)	2099.50(1114.57)
Low literal idioms in isolation	71.93(24.23)	81.58(17.66)	2822.16(1303.84)[a]	1806.17(876.51)
High literal idioms in context	77.63(23.66)	82.89(19.17)	3063.81(1358.90)[a]	2075.29(1025.49)
Low literal idioms in context	82.02(24.62)	89.47(10.56)	3106.16(1522.08)[a]	1868.13(930.99)
Reject the literal interpretation of				
High literal idioms in isolation	56.14(34.53)[a]	84.65(18.33)	2567.03(1318.08)	1668.49(938.07)
Low literal idioms in isolation	77.63(32.25)[a]	89.47(16.63)	2359.34(1036.94)	1634.93(975.64)
High literal idioms in context	71.93(27.97)[a]	87.28(16.64)	2479.97(1186.76)	1646.77(940.98)
Low literal idioms in context	75.00(32.59)[a]	92.11(13.83)	2569.40(1243.62)[a]	1571.74(732.56)

Note. Values are mean (*SD*).
[a] SBM significantly different from controls.

presented in isolation $F(1,72)=7.86$, $p=.006$ and in context $F(1,72)=8.44$, $p=.005$.

An ANCOVA model revealed that children with SBM were significantly slower than controls to reject the literal interpretation of non-decomposable idioms presented in context $F(1,69)=5.57$, $p=.021$.

3.1.2. Effects of literality

In considering how literality affects idiom comprehension, we hypothesized that children with SBM would perform more poorly on highly literally plausible idioms than their age peers because of their difficulty suppressing contextually irrelevant meaning (Barnes et al., 2004), and because highly literal idioms may cause greater competition between the literal and figurative meanings than low literal idioms. Further, the greater competition between literal and figurative meanings associated with highly literal idioms may challenge a weak comprehension system with poor suppression mechanisms. We hypothesized that children with SBM would not use linguistic context as effectively as their peers to reject the literal meaning of idioms, and also that deficits would be observed in children with SBM in the use of context to comprehend highly literal idioms because of their known deficits in integrating context for discourse coherence and in suppressing irrelevant meaning, both which may be more impaired with high literal idioms due to greater competition between the literal and figurative meanings during comprehension.

ANOVA (accuracy) and ANCOVA (speed) models were used to test between group differences on the following tasks: accepting the figurative interpretation and rejecting the literal interpretation of high literal idioms in isolation and in context and accepting the figurative interpretation and rejecting the literal interpretation of low literal idioms in isolation and in context, using clinical group (SBM vs. controls) as the grouping variable.

3.1.2.1. Accuracy. ANOVA models revealed that children with SBM performed significantly less accurately than controls in accepting the figurative interpretation of high literal idioms presented in isolation $F(1,74)=4.81$, $p=.031$ and in rejecting the literal interpretation of idioms regardless of degree of literality or linguistic context; high literal idioms in isolation $F(1,74)=20.21$, $p=.000$, and in context $F(1,74)=8.46$, $p=.005$, low literal idioms in isolation $F(1,74)=4.05$, $p=.048$ and in context $F(1,74)=8.87$, $p=.004$.

3.1.2.2. Speed. ANCOVA models revealed that children with SBM were significantly slower than controls to accept the figurative interpretation of high literal idioms presented in context $F(1,72)=7.19$, $p=.030$ and low literal idioms presented in isolation $F(1,72)=7.89$, $p=.006$ and in context $F(1,72)=9.76$, $p=.003$.

An ANCOVA model revealed that children with SBM were significantly slower than controls to reject the literal interpretation of low literal idioms in context $F(1,69) = 5.70, p = .020$.

3.1.3. Idiom comprehension and corpus callosum dysmorphology in children with SBM

Corpus callosum MRI findings for each SBM participant are reported in Table 4.

ANOVA models of accuracy scores (mean percent correct) and speed (response time in ms) were used to test between group differences. Mean latency for responding *yes* on the choice reaction time test was used as a covariate when analyzing responses that accepted the figurative interpretation and mean latency for responding *no* on the choice reaction time test was used as a covariate when analyzing responses that rejected the literal interpretation. Significant effects (i.e., $p < .05$) were followed up with Tukey's Honestly Significant Difference post hoc test using a Bonferroni corrected α level of .008 (i.e., six comparisons). This stringent level was employed to avoid making a Type I error on any one of the multiple comparisons.

3.1.3.1. Accuracy. An ANOVA model revealed a main effect of clinical subgroup for correctly accepting the figurative meanings of idioms $F(3,33) = 3.27$, $p = .033$. Post hoc tests revealed that the children in the agenesis subgroup were significantly less accurate than controls

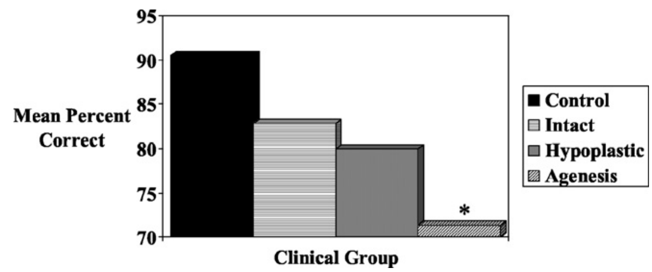

Fig. 3. Percent correct for accepting the figurative interpretation on the idiom test as a function of MRI corpus callosum group. ∗, SBM significantly different from controls.

Table 4
Corpus callosum MRI findings for participants with SBM

Participant	Rostrum	Genu	Body	Splenium
Intact				
1	Normal	Normal	Normal	Normal
2	Normal	Normal	Normal	Normal
3	Normal	Normal	Normal	Normal
4	Normal	Normal	Hypoplastic	Normal
5	Normal	Normal	Hypoplastic	Normal
6	Normal	Normal	Hypoplastic	Normal
7	Normal	Normal	Normal	Hypoplastic
8	Normal	Normal	Normal	Hypoplastic
Hypoplastic				
1	Normal	Hypoplastic	Hypoplastic	Hypoplastic
2	Agenesis	Hypoplastic	Hypoplastic	Hypoplastic
3	Hypoplastic	Hypoplastic	Hypoplastic	Hypoplastic
4	Hypoplastic	Normal	Hypoplastic	Hypoplastic
5	Normal	Normal	Hypoplastic	Hypoplastic
6	Hypoplastic	Normal	Hypoplastic	Hypoplastic
7	Agenesis	Hypoplastic	Hypoplastic	Hypoplastic
8	Hypoplastic	Hypoplastic	Hypoplastic	Hypoplastic
9	Hypoplastic	Hypoplastic	Hypoplastic	Hypoplastic
10[a]	Agenesis	Normal	Normal	Normal
Agenesis				
1	Agenesis	Hypoplastic	Hypoplastic	Agenesis
2	Agenesis	Normal	Hypoplastic	Agenesis
3	Hypoplastic	Normal	Hypoplastic	Agenesis
4	Agenesis	Normal	Hypoplastic	Agenesis
5	Hypoplastic	Hypoplastic	Hypoplastic	Agenesis
6	Hypoplastic	Hypoplastic	Hypoplastic	Agenesis
7	Agenesis	Hypoplastic	Agenesis	Agenesis
8	Agenesis	Normal	Agenesis	Agenesis

[a] *Note.* This participant did not fit into any of the above categories. This participant was placed in the hypoplastic (moderate) category due to the severity of corpus callosum agenesis observed in the rostrum, a portion of the corpus callosum that is formed later in development. This is because agenesis of the rostrum indicates that the timing of the gestational insult is more prolonged and is more consistent with the participants in the hypoplastic group (the mild or intact group did not include patients with agenesis of the rostrum and the agenesis group included only children with agenesis of the splenium).

(see Fig. 3). Percent correct (standard deviation) for each subgroup was: controls, 90.53(6.21); intact group, 82.81(11.45); hypoplastic group, 80.00(16.76); agenesis group, 71.35(17.17).

An ANOVA model for correctly rejecting the literal meanings of idioms showed no main effect of clinical subgroup.

3.1.3.2. Speed. An ANCOVA model revealed a main effect of clinical subgroup for speed of accepting the figurative meanings of idioms $F(3,32)=4.82$, $p=.007$. Post hoc tests revealed that the children in the agenesis group were significantly slower than controls (see Fig. 4). Mean response time in *ms* (standard deviation) for each group was: controls, 1756.82(828.64); intact group, 2514.06(676.55); hypoplastic group, 2924.39(1261.34); agenesis group, 3797.55(1387.84).

An ANCOVA model for speed of rejecting the literal meanings of idioms revealed a main effect of group $F(3,30)=3.02$, $p=.045$. However, post hoc tests showed no significant between-group differences.

3.1.4. Compositionality and corpus callosum dysmorphology

An ANOVA model revealed a main effect of clinical group for correctly responding (accepting the figurative and rejecting the literal meaning) to non-decomposable idioms $F(3,33)=3.76$, $p=.020$. Post hoc tests revealed that the children in the agenesis group were significantly less accurate than controls (see Fig. 5). Percent correct (standard deviation) for each group was: controls, 96.59(3.13); intact group, 80.21(19.13); hypoplastic group, 82.92(19.98); agenesis group, 75.00(12.40). An ANOVA model for correctly responding to decomposable idioms showed no main effect of group.

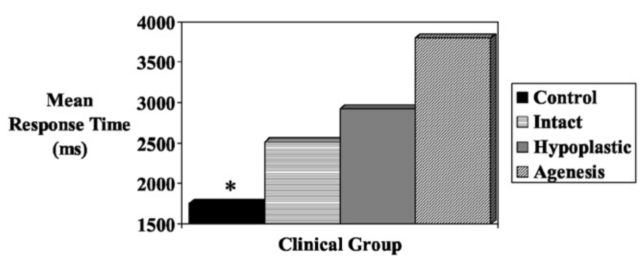

Fig. 4. Mean response time for accepting the figurative interpretation on the idiom test as a function of MRI corpus callosum group. ∗, SBM significantly different from controls.

3.1.5. Literality and corpus callosum dysmorphology

An ANOVA model revealed a main effect of clinical group for correctly responding to high literal idioms $F(3,33)=4.79$, $p=.007$. Post hoc tests revealed that the children in the agenesis group were significantly less accurate than controls (see Fig. 6). Percent correct (standard deviation) for each group was: controls, 93.18(3.85); intact group, 76.04(18.60); hypoplastic group, 77.50(20.71); agenesis group, 66.62(15.27). An ANOVA model for correctly responding to low literal idioms showed no main effect of group.

3.1.6. Specificity of the corpus callosum for idiom comprehension

Two types of analyses were performed to test the specificity of the corpus callosum for idiom comprehension: (1) an analysis of the relation between the extent of corpus callosum dysmorphology and the extent of cerebellar dysmorphology; and (2) an analysis of the relation between cerebellar dysmorphology and performance on idiom comprehension tasks. An ANOVA model of extent of corpus callosum dysmorphology (i.e., intact, hypoplastic, or partial agenesis) showed no main effect of clinical group for size of cerebellum (i.e., small or normal). Thus, some children with extensive corpus callosum dysmorphology had a normal cerebellum, and some children with an intact corpus callosum showed significant cerebellar dysmorphology.

ANOVA models were used to examine the relation between cerebellar dysmorphology and idiom comprehension. The analyses compared performance between controls, children with SBM with a normal cerebellum and children with SBM with cerebellar dysmorphology. Two separate analyses of cerebellar dysmorphology were conducted. The first analyses divided groups based on size of cerebellum and compared children with SBM rated as having a small cerebellum ($n=12$), children with SBM rated as not having a small cerebellum ($n=13$),

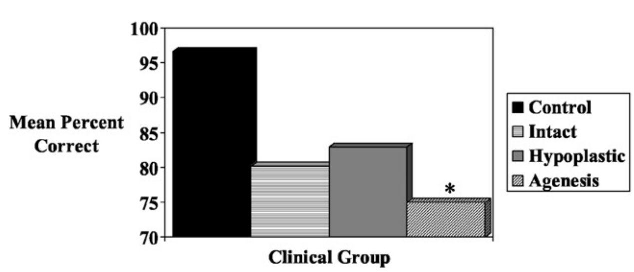

Fig. 5. Percent correct for interpretation of non-decomposable idioms on the idiom test as a function of MRI corpus callosum group. ∗, SBM significantly different from controls.

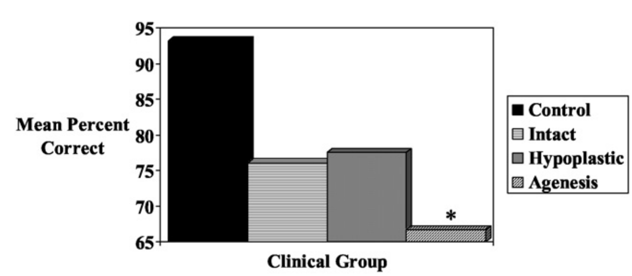

Fig. 6. Percent correct for interpretation of highly literal idioms on the idiom test as a function of MRI corpus callosum group. ∗, SBM significantly different from controls.

and controls ($n = 11$). The second analyses divided groups based on cerebellar dysplasia and compared children with SBM with cerebellar dysplasia ($n = 22$), children with SBM judged not to have cerebellar dysplasia ($n = 4$), and controls ($n = 11$). Mean test age between groups for either analyses did not differ. An ANOVA model of cerebellar size (i.e., small or normal) showed no main effect of clinical group for correctly accepting the figurative meanings of idioms, or for correctly rejecting the literal meanings of idioms. While an ANOVA model of cerebellar dysplasia did not reveal a main effect of clinical group for either correctly accepting the figurative meanings of idioms or rejecting the literal meaning of idioms, cell size is very unbalanced because most children with SBM exhibited cerebellar dysplasia, and a comparison of those without cerebellar dysplasia is not possible as sample size is too small to draw conclusions from this analysis.

4. Discussion

In this paper, we studied idiom comprehension in relation to two features of the idioms—literality and compositionality—and one feature of the biology of the language user—corpus callosum agenesis and hypoplasia. Each feature proved to affect idiom comprehension. Children with SBM had impaired idiom comprehension, a difficulty that varied not only with features intrinsic to the idioms, but also with individual differences in extent of corpus callosum dysmorphology. Compositionality, literality, and linguistic contextual bias influenced how children with SBM understood idioms. The data bear on a number of issues: the distinct core language processes associated with decomposable vs. non-decomposable idioms; the language processing deficits in children with SBM that might contribute to impaired comprehension of non-decomposable idioms and highly literal idioms and impaired suppression of irrelevant meaning; and the role of the corpus callosum in idiom comprehension deficits in children with SBM.

The *decomposition hypothesis* of idiom comprehension suggests that non-decomposable idioms cannot be compositionally analyzed so their stipulated meanings are likely learned and represented in the mental lexicon as a unit (Gibbs et al., 1989). The hypothesis proposes that the way idioms are processed varies with idiom type in adulthood (Gibbs et al., 1989), a result that has been observed during childhood acquisition (Gibbs, 1991). In typical development, young children perform poorly on non-decomposable idioms because they have not learned their stipulated meanings, but can better understand decomposable idioms, which require less knowledge of their figurative meanings. A supportive linguistic context helps young typically developing children infer, and presumably learn, the figurative meanings of non-decomposable idioms (Gibbs, 1991); linguistic context is less important for decomposable idioms in young children (Gibbs, 1991). Once the stipulated meaning has been learned, linguistic context does not facilitate the comprehension of non-decomposable idioms and older children become more proficient at non-decomposable than decomposable idioms (Huber-Okrainec, 2002).

As hypothesized, children with SBM had more difficulty with non-decomposable, context-reliant idioms than with decomposable idioms. The fact that acquisition and development of language processes associated with non-decomposable idioms can be altered due to congenital brain malformations in children with SBM shows, first, that the figurative language processes underlying non-decomposable and decomposable idioms might be partly distinct, and, second, that the functional dissociation between these two types of idioms can be demonstrated in both normal (Gibbs, 1991; Huber-Okrainec, 2002) and aberrant idiom acquisition.

The language processing limitation of children with SBM may be related to their pattern of idiom comprehension. Their preserved syntax and grammar skills for literal language (Dennis et al., 1987) may have facilitated the semantic compositional analysis of decomposable idioms, which allow use of some of the analytic tools of literal language for comprehension, regardless of context. Further, decomposable idioms require less knowledge of the stipulated meaning of idioms, whereas acquisition of non-decomposable idioms requires inferential processing from linguistic context. Children with SBM have difficulty making inferences and integrating information from context to derive meaning (Barnes & Dennis, 1998), resulting in poor acquisition and representation of non-decomposable idioms in the mental lexicon. As a result, when context is not provided, their ability to understand isolated non-decomposable idioms is poor.

In adults with right hemisphere brain damage or Alzheimer's disease, idioms have been acquired and are represented in semantic memory, so the idiom deficit may be one of retrieval of idiomatic meaning from semantic memory (Kempler et al., 1988; Papagno et al., 2003). One might argue that a further possible underlying deficit contributing to impaired comprehension of non-decomposable idioms is deficient access and retrieval from the mental lexicon. While children with SBM are slow to comprehend the figurative meanings of idioms, which could indicate deficient retrieval, their deficits may likely be due to difficulties in acquisition resulting in poor representation of non-decomposable idioms in the mental lexicon. Were their deficit due solely to an impaired ability to access or retrieve non-decomposable idioms, which are presumably learned and represented as a unit in the mental lexicon (Gibbs et al., 1989), then children with SBM would likely show deficits on picture vocabulary or single-word naming tasks, both of which require the ability to retrieve lexical information from the mental lexicon. Children with SBM, however, have preserved, albeit slow, picture vocabulary, and naming skills (Dennis et al., 1987), and are slower and less accurate at non-decomposable idioms in isolation. Their acquisition of non-decomposable idioms is less full than that of their typically developing peers, causing more difficulty in access and retrieval of non-decomposable idioms for comprehension.

Children with SBM are also slower than peers to comprehend decomposable idioms, both in isolation and in context. The *decomposition hypothesis* proposes that the stipulated meanings of decomposable idioms continue to be decomposed, even after having been learned (Gibbs et al., 1989), although the way idioms are decomposed changes throughout typical development. Early in acquisition, the literal parts of idioms are accessed and analyzed for their contribution to idiomatic meaning; later, in adolescence and adulthood, parts are analyzed more figuratively (Gibbs et al., 1989; Huber-Okrainec, 2002), which may contribute to improved comprehension speed (Huber-Okrainec, 2002). Like younger children, children with SBM may decompose the literal parts of decomposable idioms, which would not affect accuracy of comprehension of decomposable idioms compared to peers, but would slow rate of processing.

Full idiom comprehension requires that the figurative meaning be accepted and the literal meaning be rejected. Children with SBM were slower than age peers to accept the figurative interpretation of all idioms. The fact that they are slower to interpret idioms figuratively may indicate that they initially interpret the idiom literally (or, at least, analyzed the literal parts) prior to seeing the figurative picture and therefore take longer to accept the figurative interpretation because they must revise its literal interpretation. Accepting the figurative meaning produced speed but not accuracy deficits, whereas rejecting the literal interpretation produced accuracy deficits, even when a linguistic context biased the figurative meaning.

Idiom comprehension deficits have been attributed to difficulty in revising and inhibiting a literal interpretation in individuals with right hemisphere brain damage (Brownell et al., 1986; Molloy et al., 1990; Tompkins, Lehman-Blake, Baumgaertner, & Fassbinder, 2001). The difficulty that children with SBM have in rejecting the literal interpretation of idioms may be due to difficulty with literal suppression, poor discourse coherence, and impoverished inferencing abilities. Unlike typically developing children (Barnes et al., 2004; Huber-Okrainec, 2002; Levorato, 1993), children with SBM do not exploit a biasing context to reject a literal meaning that creates incoherence within discourse. Both in isolation and in context, they retain and do not suppress the inappropriate literal meaning. Further evidence for a literal suppression deficit in children with SBM is that this deficit was especially seen for rejecting the literal interpretation of highly literally plausible idioms. Highly literal idioms overpowered an already weak processing system on some idiomatic tasks in children with SBM, by making children with SBM slower and less accurate than peers. In contrast, typically developing children, who are able to suppress the literal meaning of idioms, are relatively unaffected by literality. Further, although younger, typically developing children also show difficulty comprehending idioms that are highly literal, they do not exhibit a pronounced deficit in rejecting the literal interpretation of idioms (i.e., they appear to show a similar pattern of abilities whether the task is to accept the figurative or reject the literal interpretation of idioms) (Huber-Okrainec, 2002). Semantic activation studies with children with SBM also show that children with SBM have difficulty suppressing contextually irrelevant meanings (Barnes et al., 2004).

Failure of children with SBM to suppress literal meanings of idioms is pertinent to how idioms are acquired. The fact that children with SBM can accept the figurative meaning, but are not able to reject the literal meaning, provides evidence for the broader idea that both the literal and figurative meanings are accessed when processing idioms during childhood development, and that the literal meaning must be suppressed.

Idiom comprehension deficits in children with SBM parallel the modal profile of their language deficits, which includes poor semantic–pragmatic language within the context of relatively well-preserved grammar and vocabulary (Fletcher et al., 2002). They have poor comprehension of idioms and poor suppression of the literal interpretation of idioms (like their deficits in deriving meaning from context, making inferences, discourse cohesion deficits, suppression of contextually irrelevant meaning, and comprehending context-dependent similes) but relatively preserved comprehension of decomposable idioms (like their strengths in vocabulary and grammar skills). Further, these deficits parallel their discourse production deficits (i.e., content-poor discourse that lacks coherence and contains referentially ambiguous phrases, Dennis et al., 1994). Together, the results of this study, and earlier studies investigating discourse and figurative language skills in children with SBM (i.e., Dennis & Barnes, 1993; Barnes & Dennis, 1998), suggest that children with SBM have difficulty processing figurative language that requires a contextual reference and suppression of irrelevant meaning for acquisition and comprehension.

Adult neurocognitive theories of contextual and non-literal language, including idioms, highlight interhemispheric interactions mediated by the corpus callosum (Beeman, 1993; Burgess & Chiarello, 1996; Chiarello, 1991; Faust & Weisper, 2000; Long & Baynes, 2002; Paul et al., 2003). Our data identify the importance of the corpus callosum for idiom comprehension development. As predicted, corpus callosum agenesis, especially of the splenium, body and rostrum, caused impairments in comprehension of non-decomposable idioms. Children with SBM and callosal agenesis understood idioms both less rapidly and less accurately. Corpus callosum agenesis appears to cause interhemispheric transfer deficits that disrupt figurative language comprehension. The fact that idiom comprehension was unrelated to cerebellar dysmorphology shows idiom comprehension deficits to be relatively specific to developmental anomalies of the corpus callosum. The existence of functional group differences related to corpus callosum status shows that both timing and prolongation of gestational insult may have long-term functional consequences in children with SBM for figurative language development that requires integration of contextual information and inhibition of irrelevant literal meanings. More generally, these data add to previous evidence that the corpus callosum, including the splenium, has an important role in language comprehension (Funnell et al., 2000; Gazzaniga et al., 1989).

Compared to age peers, the callosal agenesis group had idiom impairments in both accuracy and speed. Performance of the hypoplasia group was functionally sub-optimal, indicating limited interhemispheric transfer. The better performance of children with callosal hypoplasia relative to the children in the agenesis group suggests that hypoplastic transcallosal connections enable some functional interhemispheric communication for understanding idioms, which is consistent with the findings that inferences are possible after partial callosal section, but that complete callosal section disrupts inferencing abilities (Sidtis et al., 1981). While our data identify one of the cognitive processes for which transcallosal fibers appear to enable functionally sufficient, yet sub-optimal, interhemispheric transfer, knowledge of the transcallosal connections that exist in children with congenital hypoplasia of the corpus callosum remains incomplete (Hannay, 2000).

Apart from its apparent role in interhemispheric transfer for figurative language comprehension, the splenium is also important for transfer of auditory and visual information (Fischer, Ryan, & Dobyns, 1992). Auditory transfer studies using paradigms like dichotic listening in children with SBM show that laterality for verbal information is less well-established in those with agenesis of the splenium, but that laterality also is reduced in those with upper level lesions and non-right handed individuals. These factors do not appear to interact, representing independent contributions to the reduced right ear advantage (Hannay et al., 2004). Although visual transfer is not impaired in acallosal children (Ettlinger, Blackmore, Milner, & Wilson, 1974; Karnath, Schumacher, & Wallesch, 1991; Lassonde, 1994; Lehmann & Lampe, 1970), children with partial agenesis of the corpus callosum do appear to show some difficulty with transferring patterned visual information from one hemisphere to another (Hannay, 2000; Klaas et al., 1999). These difficulties have not yet been related to specific callosal structures. It is not known to what extent visual information must be integrated between hemispheres for language tasks requiring interpretation of a picture for comprehension, such as the present idiom task. Interpretation of pictures may require interhemispheric transfer of information. The extra time taken to transfer and integrate visual information, assuming it to be necessary for this task, may have contributed to the slower comprehension times observed in children with agenesis of the corpus callosum.

The poor performance of children with agenesis of the corpus callosum on highly literal idioms bears on hemispheric differences in language processing. In one characterization, the left hemisphere is a rapid processor that makes rigid and inflexible interpretive commitments (Brownell et al., 1986; Burgess & Simpson, 1988; Chiarello, 1991), whereas the right hemisphere is a slower activator of a broader range of semantic information and revises contextually irrelevant meanings (Chiarello, 1991). The agenesis group adopted a literal interpretation of high literal idioms suggesting that, in this condition, a left hemisphere literal interpretation may not be overridden because of degraded or insufficient right hemisphere figurative input.

In some theoretical accounts of idiom comprehension, both literal and figurative interpretations of idioms are accessed, with competition occurring between the two meanings before one is rejected (e.g., Bobrow & Bell, 1973; Estill & Kemper, 1982; Swinney & Cutler, 1979; Weinreich, 1969). Our data suggest that the corpus callosum may be important for resolution of this competition, and callosal agenesis may be related to poor inhibition or suppression for language, just as for sensory-motor function (Dennis, 1976). In accordance with this prediction, the difficulty of resolving the competition between figurative and literal meanings, and the revision of literal meaning, was more difficult when idioms were highly literal. Degraded and/or slower transfer of information from both hemispheres, proposed for children with SBM with partial agenesis of the corpus callosum, may make figurative information less available.

Congenital malformations of the brain often interfere with the acquisition of cognitive and language skills and this can be reflected in both rate of acquisition and quality of language development. The idiom comprehension problems of children with SBM appear to represent both language delays and language deficits. In some respects, children with SBM performed like typically developing younger children. For example, like younger, typically developing children, they had difficulty with non-decomposable idioms in isolation. In other respects, their idiom deficits were unlike those of younger typically developing peers. For example, they were able to understand decomposable idioms as well as their age peers, whereas younger children would have exhibited poorer idiom comprehension skills for both forms of idiom. Further, unlike younger children, children with SBM did not reject literal interpretations, suggesting a qualitative difference from typically developing younger children. Children with SBM exhibit idiom comprehension deficits that influence not only accuracy and speed of idiom comprehension, but the pattern of its development.

Understanding how the normal course of figurative language development can be altered by congenital agenesis of the corpus callosum in children with SBM helps to identify processes that are important for idiom comprehension, including the ability to reject the literal and accept the figurative meanings of idioms, and the use of linguistic context to make inferences about the figurative meaning of non-decomposable idioms. Further, functional dissociation between non-decomposable and decomposable idioms has provided evidence for the distinct language processes proposed for these two forms. Reciprocally, information about idiom comprehension in relation to the corpus callosum contributes more broadly to the neural basis of figurative language processing, and suggests that the corpus callosum is important for interhemispheric integration of idioms, particularly non-decomposable idioms, and that an inhibitory role of the corpus callosum may be needed for rejecting contextually irrelevant literal meanings of figurative phrases with multiple meanings.

The data are consistent with the more general idea that there are two modes of language processing, one that is compositional and propositional, the other that is configurational and non-propositional, and which includes idioms. Configurational language is distinguished from compositional language by features such as stereotyped, cohesive form, conventionalized meaning, and reliance on context (Van Lancker Sidtis, 2004). The particular relevance of our data is that differences within the broad class of idioms in compositionality and literality are shown to engage two distinct forms of language processing, only one of which is fully functional in children with SBM.

More broadly, our data suggest that the theoretical distinction between non-decomposable and decomposable idioms is meaningful at a neurological level. When children with SBM are required to process idioms from the decomposable and non-decomposable ends of the spectrum, they have more difficulty with the latter, suggesting impairment of the configurational mode of language processing, which requires more interhemispheric integration. Decoding idioms requires interhemispheric integration of the idiom with holistic-contextual information, and the impairment in non-decomposable idioms is related to congenital agenesis of the corpus callosum. The consequences of impaired interhemispheric communication, whether congenital or acquired in adulthood, are borne more by configurational than by compositional language.

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Appendix A. List of idioms rated on: Familiarity, meaningfulness, compositionality, and literality

Idiom	Frequency	Meaningfulness	Non-decomposable	Decomposable	Literality
A piece of cake	6.10 (0.16)	6.70 (0.22)	96.43	3.57	6.39 (0.34)
Break the ice	6.0 (0.20)	6.58 (0.11)	92.86	7.14	6.00 (0.27)
Bury the hatchet	5.40 (0.42)	6.35 (0.19)	75	25	6.28 (0.40)
Have cold feet	5.70 (0.34)	6.58 (0.17)	82.14	17.86	6.33 (0.38)
Hit the sack	6.20 (0.31)	6.53 (0.25)	82.14	17.86	5.94 (0.39)

(*continued on next page*)

Appendix A (*continued*)

Idiom	Frequency	Meaningfulness	Non-decomposable	Decomposable	Literality
In hot water	5.70 (0.30)	6.80 (0.03)	88.89	11.11	6.44 (0.24)
Kick the bucket	5.50 (0.43)	6.65 (0.11)	100	0	6.44 (0.32)
Over the hill	6.30 (0.13)	6.95 (0.01)	78.57	21.43	6.50 (0.28)
Pull someone's leg	5.90 (0.26)	6.90 (0.02)	89.29	10.71	5.17 (0.84)
Skate on thin ice	4.70 (0.47)	6.65 (0.05)	78.57	21.43	6.56 (0.09)
Tie the knot	6.00 (0.26)	6.90 (0.02)	92.86	7.14	6.33 (0.40)
Wear the pants	4.60 (0.69)	5.85 (0.81)	85.71	14.29	6.50 (0.28)
Be on cloud nine	5.70 (0.33)	6.93 (0.01)	88.89	11.11	1.78 (0.35)
Bite someone's head off	5.40 (0.62)	6.60 (0.32)	75	25	3.44 (0.74)
Blow someone's mind	5.50 (0.32)	6.63 (0.06)	74.07	25.93	1.83 (0.13)
Eat his words	5.90 (0.30)	6.45 (0.17)	77.78	22.22	1.94 (0.56)
Frog in one's throat	4.80 (0.60)	6.55 (0.14)	64.29	35.71	2.39 (0.44)
Give the cold shoulder	6.40 (0.10)	6.90 (0.02)	67.86	32.14	2.83 (0.43)
Paint the town	4.90 (0.69)	5.80 (0.67)	100	0	2.72 (0.46)
Pop the question	5.30 (0.42)	6.80 (0.02)	64.29	35.71	1.78 (0.39)
Rack one's brain	5.40 (0.39)	6.88 (0.02)	60.71	39.29	1.78 (0.22)
Shoot the breeze	5.60 (0.24)	6.65 (0.20)	100	0	1.83 (0.30)
Under the weather	5.20 (0.60)	6.38 (0.38)	96.43	3.57	1.67 (0.13)
With flying colors	5.70 (0.25)	6.45 (0.17)	96.43	3.57	3.00 (0.84)
Back of one's mind	5.90 (0.26)	6.70 (0.04)	35.71	64.29	4.46 (0.55)
By word of mouth	5.50 (0.49)	6.58 (0.16)	10.71	89.29	4.39 (1.07)
Call the shots	6.20 (0.27)	6.70 (0.07)	25	75	4.11 (0.86)
Hold your horses	5.90 (0.33)	6.65(0.32)	32.14	67.86	5.21 (0.83)
Lose one's touch	5.20 (0.51)	5.75 (0.49)	14.29	85.71	4.07 (0.79)
Lose your grip	6.00 (0.24)	6.40 (0.14)	14.81	85.19	5.86 (0.44)
Pass the buck	5.00 (0.73)	5.48 (0.77)	35.71	64.29	5.11 (0.82)
Play with fire	6.00 (0.26)	6.45 (0.12)	17.86	82.14	6.00 (0.43)
Shut your trap	4.90 (0.60)	6.60 (0.15)	25.93	74.07	5.21 (0.84)
Speak your mind	5.90 (0.40)	6.98 (0.00)	0	100	4.18 (0.97)
Steal the show	5.10 (0.51)	6.78 (0.03)	25	75	4.29 (0.81)
Waste your breath	5.90 (0.24)	6.78 (0.03)	28.57	71.43	5.36 (0.60)
Be the spitting image	5.80 (0.28)	6.73 (0.09)	33.33	66.67	2.14 (0.59)
Button your lip	5.40 (0.41)	6.73 (0.09)	48.15	51.85	3.11 (1.19)
Cost an arm and a leg	6.00 (0.18)	6.88 (0.02)	37.04	62.96	3.25 (0.61)
Keep a level head	5.20 (0.41)	6.60 (0.11)	25.93	74.07	3.82 (0.72)
Learn by heart	6.10 (0.34)	6.75 (0.06)	25.93	74.07	3.32 (0.91)
Learn the ropes	5.10 (0.47)	6.68 (0.08)	40.74	59.26	3.21 (0.64)
Lie through one's teeth	5.60 (0.40)	6.73 (0.06)	18.52	81.48	3.57 (1.02)
Lose your cool	5.40 (0.30)	6.65 (0.08)	17.86	82.14	3.11 (0.90)
Pour one's heart out	5.50 (0.56)	6.35 (0.22)	40.74	59.26	2.71 (0.77)
Slip one's mind	6.40 (0.21)	6.73 (0.12)	33.33	66.67	2.86 (0.78)
Talk a mile a minute	5.50 (0.47)	6.75 (0.09)	11.11	88.89	2.93 (0.93)
Would give the world	5.00 (0.55)	6.03 (0.31)	40.74	59.26	3.46 (0.94)

Note. Information in table is from Titone and Connine (1994b). Frequency, meaningfulness, and literality are in means (standard error of the mean) from 7-point rating scale. Non-decomposable and decomposable are percentage classified.

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