MIND, BRAIN, AND EDUCATION

Neuromyths Among Teachers and Student Teachers

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ABSTRACT— Many so-called brain-based educational approaches have been strongly criticized for their lack of empirical support and occasionally for their use of pseudoscientific concepts. As a result, several use the term neuromyths to refer to false beliefs or misinterpretations regarding neuroscientific facts. We surveyed both teachers and student teachers concerning their agreement toward hemispheric dominance, modality dominance, and the Brain Gym© method. Results suggest that teachers as well as student teachers believe in the reality of hemispheric and modality dominance but only a few were aware of the Brain Gym© method. Correlation analyses show moderate relationships across different beliefs and/or their perceived benefits in education. Teachers believed more than student teachers in hemispheric dominance and its pedagogical relevance. Together with other studies, the results suggest that teachers and student teachers could benefit from appropriate training in this new field of research.

The educational relevance of research data from the field of cognitive neuroscience is a matter of debate. Bruer (1997) suggested that the two disciplines should be kept apart because advances in neuroscience were still too limited to guide educational practice, whereas other authors have stressed the importance of taking this field of research into account in educational science (e.g., Byrnes & Fox, 1998). Over the past few years, several authors have emphasized the need to bring experts in both fields together in order to initiate a constructive discussion between them (Ansari & Coch, 2006; Ansari, Coch, & De Smedt, 2011; Fischer, Goswami, & Geake, 2010; Goswami, 2006; Kalra & O'Keeffe, 2011; Tardif & Doudin, 2011). Despite the fact that teachers are enthusiastic as to what neuroscience could bring to education (Pickering & Howard-Jones, 2007; Serpati & Loughan, 2012), to date there are still few direct contributions in neuroscience that can be directly applied to the classroom, and the collaborative effort between the two disciplines should be considered as a long-term process (Ansari et al., 2011; Goswami & Szűcs, 2011).

The contribution that neuroscience makes to education as well as its appeal for teachers is not without risks. Neuromyths, a term coined by the Organisation for Economic Co-operation and Development (2002), refers to misconceptions about the brain and its functions. Most of the time, neuromyths originate from research that has largely been misinterpreted or exaggerated (see Howard-Jones, 2010 for a review of different neuromyths). This seems to be the case with some approaches (e.g., Petty, 2004; Smith, 1996) claiming that teaching should be conducted in a specific way in order to keep both hemispheres "balanced" or that certain pupils present a left or right hemispheric dominance. What can appear confusing is that, although such authors present facts about the brain that are often accurate and offer advice that can indeed be of interest for teaching, the research data they rely on may be misunderstood. It is also possible that the authors interpret the results differently or that they extrapolate too much. Other approaches (e.g., Freed & Parsons, 1998) propose that individuals with attention disorder/hyperactivity deficit are in fact "right-brain" visual learners. These and other approaches based on hemispheric dominance are likely to emanate from misinterpretations of original work on hemispheric specialization carried out on split-brain patients (e.g., Gazzaniga, Bogen, & Sperry, 1965). In addition, Sperry's Nobel price brought wide public attention to the field of hemispheric specialization, which could explain why some left and right-brain theories, although actually invalid, may sound scientifically grounded for non-experts in neuroscience (see Lindell & Kidd, 2011 for a recent critical review on "right-brain teaching").

In other instances, it is not so simple to find the precise origin of a neuromyth. Indeed, some can have multiple origins that have spread in various ways throughout different educational settings. This seems to be the case with the

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so-called VAK (visual–auditory–kinesthetic) learning style model (e.g., Smith, 1996). Although the precise origin of the VAK model is unclear (see Sharp, Bowker, & Byrne, 2008 for a review) it may have been, at least in part, influenced by the discipline of neuro linguistic programming (NLP). NLP was originally developed by Bandler and Grinder (1975) and has often been criticized for its pseudoscientific nature; there is also controversy regarding its empirical support (Witkowski, 2010). For example, NLP theorists claim that visual, auditory, and kinesthetic thoughts can be identified by observing specific corresponding eye movements (e.g., Bandler, Grinder, & Andreas, 1979). Although this tenet has received partial empirical confirmation (Buckner, Meara, Reese, & Reese, 1987), most studies have failed to provide such support (see Witkowski, 2010 for a review). Moreover, the claim made by NLP practitioners that one can detect whether someone is lying by examining eye movements (e.g., Gray, 1991) has not been confirmed by recent experiments (Wiseman et al., 2012).

In French-speaking countries such as the French-speaking parts of Switzerland and Canada, the VAK model appears to have been promoted by different authors than in English-speaking countries. French author Antoine de La Garanderie emphasizes the difference between visual and auditory learners. For example, La Garanderie (1982) quotes a French Canadian author (Raymond Lafontaine) partially agreeing with somewhat preposterous affirmations such as: "The first child of a family chooses to become visual or auditory. But this choice, which is made in the very first years of life, is determined by the profile of the parent who seems to be the most confident regarding the future" (p. 125).[1] In a recent publication, Lafontaine and Lessoil (2012) fail to provide any methodological description other then "their observations" when discussing what actually led them to draw such conclusions. Moreover, the authors proposed a test, which was supposed to indicate whether a person is more visual or auditory. Again, there are no indications concerning the psychometric properties of the test, and some questions raise serious doubts as to its validity (e.g., "are you the kind of person who lives to eat?"; "Do you like to play sports alone?", p. 7).[2] To our knowledge, there is no reliable and valid instrument to measure the "modality dominance" construct and studies that have attempted to assess the internal consistency of such instruments (e.g., Barsch Learning Style Inventory; Barsch, 1991) have shown low Cronbach's alpha (.54 for visual, .56 for auditory, and .38 for kinesthetic items) and failed to establish significant correlations between modality dominance and actual performance in visual, auditory, or tactile memory tests (Kratzig & Arbuthnott, 2006).

Another method claiming to be "brain-based" is what is known as educational kinesiology and has been popularized under the name of Brain Gym© (Dennison & Dennison, 1994). The method proposes a series of exercises, which are supposed to enhance different learning abilities, including academic skills. However, few peer-reviewed studies have been conducted to assess their effectiveness and the supposed benefits remain unproven (e.g., Spaulding, Mostert, & Beam, 2010). The method itself seems to stem from previous controversial theories such as Orton's mixed cerebral dominance (Orton, 1937), perceptual motor training (e.g., Barsch, 1965), and neurological repatterning (the Doman-Delacato approach; Doman, 1968). Some of these approaches have been severely criticized and warnings have been issued as concerns their unfounded theoretical background and lack of empirical validation (e.g., Ziring et al., 1999). In 2008, the British charitable trust "Sense About Science" published a short communication in which they asked academic experts their opinions about various statements made by Dennison and Dennison (1994), most of them concerning the claimed effects of Brain Gym© exercises on brain functioning. Experts largely dismissed all affirmations and the approach was depicted as pseudoscientific.[3]

Although several publications stress the presence of neuromyths in the field of education (e.g., Ansari & Coch, 2006; Geake, 2008; Goswami, 2006; Lindell & Kidd, 2011; Organisation for Economic Co-operation and Development, 2002; Pasquinelli, 2012; Tardif & Doudin, 2011), few studies have sought to verify directly with the teachers the extent of false (or correct) beliefs regarding neuroscientific facts (Dekker, Lee, Howard-Jones, & Jolles, 2012; Howard-Jones, Franey, Mashmoushi, & Liao, 2009). These studies suggest that a large number of teachers and student teachers are exposed to pedagogical methods claiming to be "brain-based" but that they have limited knowledge and some misconceptions about neuroscientific facts. Dekker et al. (2012) showed that three neuromyths were the most widespread among teachers, namely that (1) learning can be enhanced by using the VAK approach, (2) hemispheric dominance (left brain vs. right brain) can explain individual differences among learners, and (3) shorts exercises can improve left and right hemispheric integration (as claimed by the Brain Gym© method). In the sample studied by the authors, more than 80% of respondents believed those myths to be true. Moreover, results suggest that, although respondents who regularly read popular science magazines had better scores on general knowledge questions, more general knowledge was also associated with greater belief in neuromyths.

As mentioned earlier, some neuromyths can be subject to cultural differences (e.g., the VAK approach in French- and English-speaking countries has been promoted by different authors). Although some differences have been observed between teachers across countries (Dekker et al., 2012), recent data indicate that teachers from very different cultures may also believe in similar neuromyths (Howard-Jones, 2014). Because it is often difficult to determine the sources

of the teachers' beliefs, one might also question whether student teachers could already have such beliefs, and if there are any differences between these two populations. A better understanding of student teachers' beliefs would be of great help in order to develop better teacher training programs (e.g., Hollingsworth, 1989). We therefore asked teachers, student teachers, and teachers' trainers from the French-speaking part of Switzerland to state to what extent they agreed with different affirmations related to the three aforementioned neuromyths. Another objective of the present study was also to extend the results of Dekker et al. (2012), by verifying to what extent the respondents believed that these neuromyths (1) are supported by brain research, (2) whether they agreed that a pedagogical approach based on such concepts would favor learning, and (3) whether they would consider using them as part of their teaching practices. In addition, they were also asked to specify their source of information regarding these approaches (e.g., media, school, colleague, etc.). In addition, we sought to determine (using correlation analyses) whether the belief of some respondents in neuromyths was more general, and whether those who believed more strongly in such myths were also more likely to implement associated approaches in their practices. Through this work, we hope to better understand which beliefs need to be clarified in both in-service teachers and in student teachers.

METHOD

Participants

Two hundred and eighty-three individuals participated in the study, which was conducted in the French-speaking part of Switzerland. Forty-four (22 females) were in-service high-school teachers (recruited via two schools), 57 (24 females) were college teachers (recruited via one school), 160 (141 females) were first-year primary student teachers (recruited via one group), and 22 were teachers' trainers (recruited via in-service training course). Subjects were asked to indicate which of the following age categories they belonged to: (1) ≤21 years old; (2) 21–30 years old; (3) 31–40 years old; (4) ≥40 years old. Percentages of subjects according to group status and age group are shown in Table 1. As expected, students were more represented in the two youngest categories and less in the two older categories, $\chi^2(9, N = 281) = 188.96$, $p < 0.001$ (two subjects did not mention their age and were excluded from this analysis).

Table 1
Percentage of Student Teachers, Teachers, and Teacher Trainers Across Age Groups

	≤20 y/o	*21–30 y/o*	*31–40 y/o*	*≥41 y/o*
Student teachers ($n = 160$)	41[a]	53[a]	4[a]	2[a]
College teachers ($n = 57$)	0[b]	16[b]	47[b]	37[b]
High-school teachers ($n = 44$)	0[b]	11[b]	34[b]	55[b]
Teacher trainers ($n = 22$)	0[b]	23[b]	32[b]	45[b]

Note. Within each column (age category), percentages featuring the same superscript letter (a or b) show no significant differences between the proportions of subjects across status groups at $p < 0.05$. Student teachers were more represented in the two youngest age groups and less in the two oldest age groups.

Questionnaire

The general organization of the questionnaire was the same for the three neuromyths (hemispheric dominance, modality dominance, and Brain Gym©). Since the French-speaking authors mentioned earlier only refer to visual and auditory individuals, we limited our questions to these two styles and did not mention kinesthetic dominance. For each neuromyth, we asked to what extent the subject agreed or disagreed with four statements. For most statements, a Likert scale was coded as follows: 1 = *totally disagree*; 2 = *somewhat disagree*; 3 = *somewhat agree*; 4 = *totally agree*. The first question about Brain Gym© (i.e., "I know Brain Gym©") was coded as: 1 = *not at all*; 2 = *a little*; 3 = *rather well*; 4 = *a lot*. Its frequency of use with the students (i.e., "I have used Brain Gym© with my students") was coded as: 1 = *never*; 2 = *rarely*; 3 = *often*; 4 = *very often*. Three statements addressed the subjects' beliefs concerning each neuromyth: whether they agreed with it (e.g., "Some people use their left hemisphere—left brain—more, whereas others use their right hemisphere—right brain–more"), whether they thought that it was supported by brain research (e.g., "Brain research has demonstrated that some people use one hemisphere more than the other"), and whether it could have a pedagogical relevance (e.g., "A pedagogical approach based on the distinction between left and right brain functions favors learning"). One question was related to teachers' actual practice (e.g., "I take into consideration the distinction between pupils who use one hemisphere—left or right—more than the other in my teaching practice in my teaching practice"). For student teachers, the question was adapted in "I intend to consider the distinction … in my future teaching practice". Three additional statements were also introduced: one was true ("The two hemispheres of the brain may be responsible for different functions") and the two others were false ("The two hemispheres of the brain work independently from each other"; "Brain Gym© allows pupils to better understand how their body works"). Finally, for each neuromyth, we asked the subject to state the source through which the information was obtained (readings, course in high school or college, teacher training course, fellow worker, colleague or friend, media—newspapers,

radio, television or the Internet—or another source). For this question, several choices were allowed. Information about gender and age were also collected.

Data Analyses

The data were analyzed using the Statistical Package for the Social Sciences (SPSS) software (V.21) for MacOS. As the preliminary analyses (means comparisons) did not show differences between secondary and college teachers, these were considered as a single "teachers" group. The 22 trainers were also included in the teachers group. Statistical analyses other than descriptive could not be performed on the trainers' sample due to its small size. First, in order to compare with previous studies (Dekker et al., 2012), all subjects were first considered as a single group, and answers coded 1 and 2 were grouped together as *disagree* and 3 and 4 as *agree*. Beliefs and practices related to hemispheric dominance, modality dominance, and Brain Gym© were presented successively. Second, correlations were performed across the different beliefs, perceived benefits of such methods, and their actual classroom practices. This was carried out using the subjects' responses on the 4-point Likert scale. Thirdly, we aimed to determine whether teaching status (teachers vs. student teachers) could influence the extent of beliefs in neuromyths. Because the primary student teachers were mostly females and were younger than the teacher group, we performed analyses of covariance (ANCOVAs) using status as independent variable and age and gender as covariables. The dependent variable was the degree of agreement with neuromyths using the above-mentioned 4-point Likert scale. Analyses were limited to questions pertaining to modality and hemispheric dominance (questions about Brain Gym© were excluded because too few subjects were aware of the method). For all analyses, agreement with the main statement (e.g., "some individuals are visual and other are auditory"), the fact that it was supported by brain research, its pedagogical relevance, and whether they were using (or intending to use) such a distinction in their teaching practices were used successively as dependent variables.

RESULTS

Hemispheric Dominance

Mean values obtained on statements associated with hemispheric dominance are shown in Table 2. Taken together, subjects tend to agree with the statement that some people use one hemisphere more than the other ($M = 3.01$, $SD = 0.64$), that this is supported by brain research ($M = 2.93$, $SD = 0.62$) and that a pedagogical approach based on such distinction (i.e., left-brain vs. right-brain individuals) would favor learning ($M = 2.61$, $SD = 0.72$). However, they did not report significant use of such distinction in their teaching practice ($M = 1.97$, $SD = 0.79$). Percentages of agreements (i.e., *totally agree* and *somewhat agree*) with

Table 2
Percentage of Agreements With Affirmations

	All subjects (n = *283*)	
	% Agreements	*M* ± *SD*
Hemispheric dominance		
"Some people use their left hemisphere (left brain) more whereas others use their right hemisphere (right brain) more"	**85** (225/264)	3.0 ± 0.6
"Supported by brain research"	**83** (212/256)	2.9 ± 0.6
"A pedagogical approach based on such a distinction favors learning"	**63** (156/249)	2.6 ± 0.7
"Use/intend to use this distinction in teaching practices"	**27** (72/268)	2.0 ± 0.8
"The two hemispheres can be responsible for different functions"	**93** (242/261)	3.3 ± 0.7
"The two hemispheres work independently from each other"	**51** (135/265)	2.5 ± 0.8
Visual-auditory		
"Some individuals are visual, others are auditory"	**96** (269/280)	3.5 ± 0.6
"Supported by brain research"	**85** (213/250)	3.0 ± 0.6
"A pedagogical approach based on such a distinction favors learning"	**87** (238/274)	3.0 ± 0.6
"Use/intend to use this distinction in teaching practices"	**80** (223/280)	3.0 ± 0.7
Brain Gym©		
"I know Brain Gym©"	**18** (52/283)	1.2 ± 0.5
"Brain Gym© is supported by brain research"	**79** (33/42)	3.0 ± 0.7
"Brain Gym© favors learning"	**88** (37/42)	3.0 ± 0.5
"Use/intend to use Brain Gym© with students"	**65** (30/46)	1.9 ± 0.8
"Brain Gym© helps understanding how the body works"	**55** (26/47)	2.7 ± 0.7

Note. Bold numbers represent the percentage of "totally agree" or "somewhat agree". The percentage is derived from the number of agreement divided by the total number of answered questions (showed in parenthesis). Means ± *SD* are derived from the 4-point scale: 1 = *totally disagree*; 2 = *somewhat disagree*; 3 = *somewhat agree*; 4 = *totally agree*.

Table 3
Sources Through Which Subjects Were Informed

	All subjects (N = 283) %	*Teachers & trainers (N = 123) %*	*Student teachers (N = 160) %*
Hemispheric dominance			
Readings	26	41	15
School or college	14	7	19
Teacher training course	7	15	2
Colleague, friend	11	11	12
Media	32	40	26
Others	7	8	7
Visual-auditory			
Readings	29	44	18
School or college	15	12	18
Teacher training course	18	29	9
Colleague, friend	20	13	26
Media	29	32	27
Others	15	11	18
Brain Gym©			
Readings	3	5	1
School or college	2	2	2
Teacher training course	1	1	0
Colleague, friend	8	10	6
Media	5	7	4
Others	3	4	2

statements related to hemispheric dominance are shown in Table 2. When all subjects were considered as a group, 85% agreed that some people use one hemisphere more than the other and 83% agreed that this was supported by brain research. Although only 27% did (or intended to) consider this distinction in their professional practice, 63% considered that a pedagogical approach based on such a distinction would favor learning. Also, although the vast majority of subjects (93%) were aware that the two hemispheres can be responsible for different brain functions, half of them (51%) agreed that the two hemispheres worked independently from each other. Regarding the sources through which subjects reported having been informed about the distinction between individuals using one hemisphere more than the other, results are presented separately for teachers (including trainers) and for student teachers (Table 3). Since multiple answers were possible, results are presented as percentages of *yes* for each choice. Media was the most prevalent in the two groups (40% for teachers and trainers; 26% for student teachers) followed by readings (41% in teachers and trainers) and school or college (19% in student teachers). Fifteen percent of the teachers and trainers had been informed about hemispheric dominance through a teacher training course.

Modality Dominance

Mean values obtained on statements related to modality dominance are shown in Table 2. Taken together, subjects strongly agreed with the fact that some people are visual while others are auditory ($M = 3.45$, $SD = 0.61$), with the fact that this was supported by brain research ($M = 2.98$, $SD = 0.62$), and that a pedagogical approach based on such a distinction would favor learning ($M = 2.99$, $SD = 0.60$). Moreover, subjects reported taking this distinction into account in their teaching practices ($M = 2.93$, $SD = 0.73$). Percentages of agreements (i.e., *totally agree* and *somewhat agree*) with statements related to modality dominance are shown in Table 2. The large majority of respondents (96%) agreed with the assumption that some individuals are visual while others are auditory. Most subjects (85%) also agreed that such a distinction was supported by brain research. Eighty-seven percent agreed that a pedagogical approach based on such a distinction would favor learning, and 80% of the subjects claimed that they used (or intended to use) the distinction between visual and auditory pupils in their practice. Regarding the sources through which subjects reported having been informed of the distinction between visual and auditory individuals (Table 3), teachers and trainers mostly reported readings (44%), media (32%), and teacher training course (29%). Student teachers mostly reported media (27%) and colleague or friend (26%).

Brain Gym©

Mean values obtained on statements related to Brain Gym© are shown in Table 2. We first asked subjects whether they knew about Brain Gym©. If the answer was *not at all*, subjects were asked to skip the associated questions. Less than 20% of subjects said they knew at least *a little* about Brain Gym©. Among these, mean values indicate a general agreement with the fact that they believed it was supported by brain research ($M = 3.01$, $SD = 0.68$), that it would favor learning ($M = 3.02$, $SD = 0.51$), and that it would help better understand how the body works ($M = 2.70$, $SD = 0.74$). However, Brain Gym© was not reported to be frequently used with students ($M = 1.92$, $SD = 0.81$). Percentages of agreement (i.e., *totally agree* and *somewhat agree*) with statements related to Brain Gym© are shown in Table 2. Among the 283 respondents, 45 knew *a little* (15 teachers, 21 student teachers, and 9 trainers), 5 knew *rather well* (2 student teachers and 3 trainers), and 1 trainer and 1 student knew *a lot*. Among the subjects who knew about Brain Gym©, 79% (33 subjects) agreed that it was supported by brain research, 88% (37 subjects) agreed that it favored pupils' learning, and 65% (30 subjects) used (or intended to use) this method with their pupils. Fifty-five percent (26 subjects) agreed with the statement that Brain Gym© allowed pupils to better understand how their body works. Teachers' trainers had the larger proportion of participants who knew

about Brain Gym© (59%; 13/22 subjects). Within this particular group, among the 13 subjects who knew at least *a little* about Brain Gym©, 8 agreed with the fact that it was supported by brain research and only one *rather disagreed*. The three other subjects did not answer the question. Regarding the sources through which subjects reported having been informed about Brain Gym© (Table 3), colleague or friend was the main source (10% for teachers and trainers; 6% for student teachers) together with media (7% for teachers and trainers; 4% in student teachers). Five percent of teachers and trainers reported reading as being a source of information about Brain Gym©.

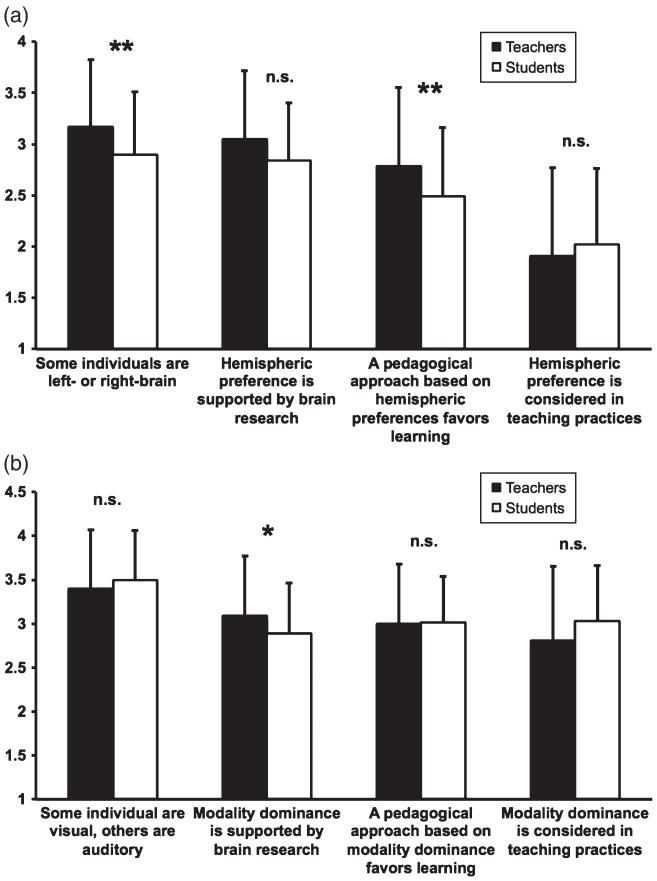

Fig. 1. Mean scores on affirmations regarding hemispheric preferences (a) and modality dominance (b) for teachers and student teachers. *Y*-scale values range from 1 *totally disagree* to 4 *totally agree*. Error bars represents standard deviations. $^{*}p < 0.5$; $^{**}p < 0.01$.

Correlation Analyses

Correlation analyses were performed across all questions associated with hemispheric dominance and modality dominance using the responses on the 4-point Likert scale. Questions related to Brain Gym© were not included in the analyses due to the limited number of subjects who were aware of the method. When all subjects were considered together, a weak but significant correlation was found between beliefs in hemispheric dominance and in modality dominance ($r = 0.16$; $p < 0.01$). Belief in modality dominance was also correlated with the belief that such approach favored learning ($r = 0.24$, $p < 0.01$) and with the belief that a pedagogical approach based on hemispheric dominance favored learning ($r = 0.18$, $p < 0.01$). Belief in hemispheric dominance was correlated with belief that such a pedagogical approach would favor learning ($r = 0.35$, $p < 0.01$) and with the actual or intended use of this approach in practice ($p = 0.30$, $p < 0.01$). Other correlations did not reach significance.

Influence of Teaching Status

ANCOVAs were performed successively using status (teachers vs. student teachers) as independent variables and gender and age group as covariables. Dependent variables were agreement with the four statements related to hemispheric dominance and modality dominance. Preliminary analyses were performed and showed no differences between college versus high-school teachers on agreement with neuromyths. As trainers constituted a rather small sample ($n = 22$), they were added to college and high-school teachers to form a unique "teachers" group. No gender or age interactions were found across all analyses performed. As illustrated in Figure 1a, ANCOVA showed that teachers ($M = 3.17$, $SD = 0.65$) agreed more with the fact that "Some people use their left hemisphere—left brain—more, whereas others use their right hemisphere—right brain—more" than did student teachers ($M = 2.90$, $SD = 0.61$) $F(1, 259) = 6.7$, $p < 0.01$. Effect size associated with the independent variable (status) was $d = 0.42$, which can be interpreted as moderate effect. Teachers ($M = 2.78$, $SD = 0.76$) also agreed more than student teachers ($M = 2.49$, $SD = 0.67$) with the statement that a pedagogical approach based on the distinction between left and right-brain functions favored learning $F(1, 243) = 13.32$, $p < 0.01$. The effect size associated with status reached $d = 0.40$. No other significant influence of status was found for hemispheric dominance (i.e., teachers and student teachers did not differ in the statement that they believed it was supported by brain research or in their actual or intended consideration of it in their practices). Regarding modality dominance (Figure 1b), ANCOVA showed that teachers ($M = 3.09$, $SD = 0.68$) believed more that modality dominance was supported by brain research than did student teachers ($M = 2.89$, $SD = 0.57$), $F(1, 244) = 4.92$, $p < 0.05$. The effect size associated with the independent variable was $d = 0.32$. No other significant influence of status was found for modality dominance (i.e., teachers and student teachers did not differ on their agreement with the neuromyth, in their actual or intended consideration of it in their practice or in its pedagogical relevance).

DISCUSSION

This study investigates the extent to which teachers, student teachers, and teachers' trainers believe in hemispheric dominance, modality dominance, and the benefits of the Brain Gym© method. Previous studies suggest that these three neuromyths are considered the most widespread among teachers (Dekker et al., 2012). Furthermore, we asked respondents if they thought that these statements were supported by brain research, whether a pedagogy based on such conceptions would be likely to favor learning, and if they would take them into account in their teaching practices. In general, our results show that teachers (either college or secondary) and teachers' trainers, as well as student teachers, believed that some individuals use one hemisphere more than the other and that some are more visual whereas others are more auditory. On the other hand, relatively few subjects in the present study were aware of the Brain Gym© method.

Hemispheric Dominance

Regarding hemispheric dominance, our data are very similar to those reported by Dekker et al. (2012). In our study, 85% of respondents agreed that some people use one hemisphere more than the other; Dekker et al. (2012) found that nearly 90% of teachers believed that differences in hemispheric dominance could help explain individual differences among learners. Despite this strong agreement with the concept of hemispheric dominance, only 27% of the subjects surveyed in the present study reported they would consider taking it into account in their teaching practice. However, most (63%) agreed that a pedagogical approach based on such distinction could favor learning. A fairly high number of teachers could therefore be considered to be "vulnerable" to so-called brain-based approaches such as "right-brain teaching" if such approaches were to be introduced to them, especially if they were presented as "brain-based." Indeed, several studies have shown that people tend to agree more with statements (either true or false) when these are accompanied by brain-related confirmations or images of brain activations (see Beck, 2010). This should represent a warning for higher instances of Swiss education because such pseudoscientific teaching approaches seem to be already implemented in some countries (Dekker et al., 2012; Howard-Jones, 2009; Lindell & Kidd, 2011).

Modality Dominance

Modality dominance also seems to be a well established belief in teachers and student teachers. Indeed, 96% of respondents in our sample fully agreed or somewhat agreed that some individuals are visual while others are auditory, and around 95% of teachers surveyed by Dekker et al. (2012) believed that individuals learn better when they receive information adapted to their preferred learning style. It is possible that these two statements may have been interpreted somewhat differently. This will be discussed in further detail when addressing the limitations of the study. However, this tends to confirm that, although the origins of certain neuromyths may differ across cultures (e.g., authors such as Antoine de La Garanderie in the French-speaking part of Switzerland vs. Alister Smith in the United Kingdom), the myths nonetheless seem to be rather widespread among teachers across these different countries. Unlike hemispheric dominance, it appears that a great majority of teachers and student teachers (80%) in our sample already consider (or intend to consider) modality preferences in their teaching practices. In terms of training (either in-service training or pre-service training), this poses a rather difficult challenge when trying to change their current practices. We have anecdotal evidence that in-service teachers strongly reacted when presented with empirical data challenging the efficiency of matching learning material with preferred modality (i.e., one teacher claiming that "one should not question anything that Mr. de La Garanderie stated"). Studies have shown that student teachers begin their training with pre-existent beliefs about teaching (e.g., Holt-Reynolds, 1992) and some authors agree that teachers may rely more on beliefs than on actual knowledge in their practices (e.g., Doudin, Pons, Martin, & Lafortune, 2003; Pajares, 1992). Nevertheless, it seems clear from previous studies that students' beliefs (or "personal practical theories") influence their future practices within the classroom and that these beliefs are themselves influenced by a number of factors including personal experience and knowledge acquired as part of their educational training (Chant, 2002). While some authors raise a number of arguments suggesting that such beliefs are rather difficult or impossible to modify (e.g., Pajares, 1992), others claim that confronting common beliefs with empirical data could indeed modify some of these beliefs (Doudin et al., 2003; Fenstermacher, 1978).

Brain Gym©

Given our personal experience with teachers, we found it rather surprising that less than 20% of our respondents actually knew at least *a little* about Brain Gym©. One explanation could be that some may refer to *kinesiology* without linking it to the *educational kinesiology* of Dennison and Dennison (1994) and to Brain Gym©. However, those who were aware of the method (including about half of the teachers' trainers surveyed) mostly agreed that it was supported by brain research and that it would favor learning. One explanation could be that those who were aware of it were probably more interested in it, or more easily convinced by the fact that it would work. Dekker et al. (2012) also found mixed results across countries regarding Brain Gym©; it

was much more commonly encountered in U.K. schools (82%) than in the Netherlands (8%). Although conducted in a limited number of schools, these preliminary results suggest that, at least in some countries, this pseudoscientific approach is still only known by a limited number of teachers and student teachers and that its use may therefore be easier to prevent through adequate training.

Relationships Among Neuromyths, Perceived Benefits, and Classroom Practices

We also found a number of significant positive correlations between beliefs in neuromyths and their perceived pedagogical relevance as well as their use with students. This tends to confirm that neuromyths are not limited to simple beliefs but are also perceived as useful within the educational context by those who adhere to them. Moreover, we found a positive correlation between different neuromyths (beliefs in hemispheric dominance were positively correlated with beliefs in modality dominance). This could indicate that some teachers and student teachers are more likely than others to believe in neuromyths in general. However, correlation coefficients ranged between 0.16 and 0.35, indicating rather small relationships between variables. It is therefore possible that some participants believed in some neutomyths but did not find them relevant for education or did not know how to use them in their practices. Beliefs in neuromyths, their perceived benefits, and classroom practices may also be influenced by other variables that were not assessed here.

Implications for Teacher Training

Because teachers seem to consider brain functioning to be relevant within the educational context (Pickering & Howard-Jones, 2007), several authors have pointed out the relevance of including basic training in research and cognitive neuroscience in the teacher training curriculum (Ansari & Coch, 2006; Goswami, 2006; Tardif & Doudin, 2011). This could help future teachers to have a better understanding of research results and to critically examine information they receive from multiple sources. However, neuroscience should be regarded as a means to better understand a number of topics relevant to education rather than as a prescriptive tool for teachers (Ansari & Coch, 2006). Moreover, as the relatively new field of educational neuroscience is facing a number of issues (see, e.g., Willingham, 2009), it must develop on the basis of a two-way dialogue between researchers and practitioners in order to raise research questions relevant to multiple learning situations (Fischer et al., 2010).

One important result of the present study is that 29% of teachers and trainers stated that they became aware of the fact that some individuals are auditory while others are visual during a course as part of their teacher training. This raises serious questions concerning the teacher training curriculum and, implicitly, the training that education teachers themselves should receive. Although our sample of teachers' trainers was very limited, the large majority of them agreed with all statements related to modality dominance (including its pedagogical relevance) and are therefore likely to influence their students on the merit of such an approach. Student teachers were at the beginning of their training (this means that some of them might have been informed later on in their training). Nevertheless, 9% of them had already heard about this distinction in the course of their training. This might also partly explain the result showing stronger beliefs in teachers versus student teachers regarding certain neuromyths and their possible use in practice: those beliefs may partly be acquired through their teacher training. Moreover, when young teachers join a new school, they might be greatly influenced by more experienced teachers, therefore consolidating their own beliefs with respect to approaches that are used by senior teachers. According to Sharp et al. (2008), information relative to the VAK approach seems to be mainly transmitted through "word of mouth" among teachers. Also, some schools and/or universities for teacher education in Switzerland currently offer in-service training to VAK-like approaches (e.g., La Garanderie, 1982) and to the Brain Gym© method. This may partly explain why in-service teachers may show stronger beliefs in neuromyths than students.

Limitations of the Present Study

The results obtained in the present study are limited in their interpretation by a certain number of factors. One of these is that the respondents represented a distinct sample, which may be representative of a limited locality within the French-speaking region of Switzerland. More importantly, most questions were formulated in terms of assertions with which subjects were asked to state whether they agreed or disagreed, which differs somewhat from the "true or false" statements used by Dekker et al. (2012). In the present study, some respondents may have assessed some statements in ways that did not necessarily correspond to a neuromyth. For instance, they might have believed that "Some people use their left hemisphere—left brain—more, whereas others use their right hemisphere—right brain—more" simply because they had heard about the crossed nature of the motor system and that right-handed individuals would therefore be likely to use their left hemisphere more than the other (and vice versa). Despite such possible interpretations, it remains that the statement in itself is false since it is not supported by recent brain imaging data on neuronal connectivity (Nielsen, Zielinski, Ferguson, Lainhart, & Anderson, 2013). The case is somewhat different for the statement related to modality preference, "some individuals are visual whereas others are auditory." This statement does not offer any real

possibility to verify whether the respondent's interpretation implies a belief about modality preferences (which is not a myth) or the belief that matching the learning material with the preferred modality would be more effective, which has not been confirmed experimentally (see Pashler, McDaniel, Rohrer, & Bjork, 2008). However, within an educational context, the fact that teachers and student teachers agree with this statement is likely to imply the belief that a pupil will learn better if presented with the preferred material. Moreover, the fact that a large number of subjects claim to take into account modality preferences in their teaching practices supports the hypothesis that they believe in the learning efficiency of such matching.

The use of positive statements may also have led to some acquiescence bias. Thus, the strong agreement with some questions may have been amplified by such bias. However, this tendency to agree with positively formulated questions has mostly been demonstrated in personality scales (e.g., Jackson & Messick, 1958; Rammstedt & Farmer, 2013). Clearly, the questions put to the respondents in the present study are far less personal and subject to factors such as social desirability. In addition, this bias is more important in low-income regions and in lower educated subjects (e.g., Meisenberg & Williams, 2008), which is not the typical profile of teachers and student teachers surveyed in the present study (in Switzerland, student teachers must have completed college studies to be admitted for training). Moreover, we found considerable variability among responses, which allows to draw some conclusions such as the fact that the VAK approach is currently more considered in the classroom than hemispheric preference.

In conclusion, the present results confirm and extend those of Dekker et al. (2012) in that hemispheric and particularly modality dominance are well established beliefs in teachers and student teachers. This suggests that if any "brain-based" education were to be developed, this should definitely start with a particular awareness enhancement of teachers and student teachers in order to enable them to critically evaluate different pedagogical approaches and their underlying theoretical and empirical background. From our point of view, this would necessarily imply close collaboration between scientists, researchers, and practitioners.

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NOTES

1 Translated from French.
2 Translated from French.
3 http://www.senseaboutscience.org/resources.php/55/sense-about-brain-gym

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