Australian Journal of Teacher Education

Volume 45 | Issue 10 Article 6

2020

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Abstract: The term neuromyths refers to misconceptions about learning and the brain. Educator neuromyths may result in inappropriate instruction, labelling of learners, and wasted resources. To date, little research has considered the sources of these beliefs. We surveyed 1359 Australian preservice educators (M = 22.7, SD = 5.7 years) about their sources of information for 15 neuromyth and 17 general brain knowledge statements. Consistent with previous studies, neuromyth beliefs were prevalent. Predictors of neuromyth accuracy included general brain knowledge and completion of university classes addressing neuromyths, although effects were modest. Depending on the belief, participants relied on general knowledge, academic staff, school staff, and popular media. Recommendations for teacher education are presented.

Introduction

Neuromyths are misconceptions about learning and the brain that are incorrect, incomplete, or have been inappropriately extrapolated from sound science (Organisation for Economic Co-operation and Development, 2007). These misconceptions include, but are not limited to, beliefs about: the effect of music on the brain, sensory learning styles instruction, sugar and hyperactivity, and so-called hemispheric dominance dictating creativity and logic (i.e., left brain-right brain learning). Like other scientific misconceptions, researchers have found widespread belief in many neuromyths among the general public. These include belief that teaching matched to preferred learning styles improves acquisition, listening to classical music improves reasoning and that differences in hemispheric dominance (left brain, right brain) can help explain individual differences amongst learners (Macdonald et al., 2017). More worryingly for school systems and students, however, research to date has also provided evidence of neuromyth beliefs among surveyed educators (e.g., Bellert & Graham, 2013; Dekker et al., 2012; Howard-Jones, 2014; Macdonald et al., 2017; Ruhaak & Cook, 2018), preservice educators (e.g., Canbulat & Kiriktas, 2017; Düvel et al., 2017; Ferrero et al., 2016; Gleichgerrcht et al., 2015; Grospietsch & Mayer, 2018; Howard-Jones et al., 2009) and higher education academics (Newton & Miah, 2017).

Neuromyths Prevalence

Neuromyths are remarkably prevalent. Ferraro et al. (2016) analysed prevalence of neuromyths across countries and found that learning styles instruction was believed by over 80% of teachers in all countries. Similarly, the belief that "environments that are rich in stimulus improve the brains of preschool children" was believed by over 80% in all countries, except the Netherlands. For other beliefs there was considerable variation across countries and cultures (e.g., belief that children must acquire their native language before a second language is learned, hemispheric dominance explains differences among learners). Macdonald et al. (2017) argued that it is important to examine the prevalence of neuromyths in different educator cohorts, given the substantial variation in teacher preparation practices. To date, however, there appears to have been only limited research with preservice educators in the Australian educational context. Kim and Sankey (2018) surveyed 1,114 first year undergraduate pre-service teachers on five neuromyth statements. More than 97% believed in modality-based learning styles instruction (i.e., teaching to visual, auditory or kinaesthetic learning styles), while more than 80% endorsed three other neuromyths. In a national survey of final year students enrolled in teacher education programs, Carter et al. (2015) found that a large proportion of students believed learning styles instruction had a strong evidence base and intended to use this approach to teaching. The extent of acceptance of other common neuromyths, however, remains unknown.

Does Acceptance of Neuromyths Matter?

A pertinent question is whether it matters that educators or preservice educators accept neuromyths. Belief in neuromyths may, for example, lead to inappropriate or ineffective teaching (Organisation for Economic Co-operation and Development, 2007). If this is the case, dispelling neuromyths is of critical importance. Similarly, Dekker et al. (2012) have argued that belief in neuromyths may result in wasted resources, such as effort, time and money, that could be better invested in effective educational practices. Finally, and in relation to the learning styles instruction myth specifically, Nancekivell et al. (2019) have argued that neuromyths are not simply viewed by believers as benign preferences. Rather, according to believers, neuromyths such as learning styles have an "effect on life and learning" (p.12). As a consequence, beliefs in neuromyths may result in inappropriate labelling of learners, the depletion of educational resources, and inappropriate instruction (Scott, 2010). Moreover, accurate identification of neuromyths is associated with intention to implement effective instructional practices (Ruhaak & Cook, 2018). Thus, it can be argued that neuromyths are not simply innocuous misinterpretations by educators, but potential drivers of instruction.

Nevertheless, some have argued that belief in neuromyths may not be detrimental to teacher effectiveness. Horvath et al. (2018) found little difference between the neuromyth beliefs of award winning and non-award winning teachers across education sectors. They therefore argue that the suggested connection between neuromyth belief and lower teaching effectiveness may itself be a myth. This interpretation requires the assumption that awards are given on the basis of measured student outcomes, reflecting teaching effectiveness. Examination of the criteria or guidelines for several of these awards suggests this is not the case. There is typically a focus on teacher innovation, learning culture, motivation, and inspiration, but few, if any, criteria related to objectively measured student learning (e.g., Office of Superintendent of Public Instruction, n.d; Pearson National Teaching Awards, 2019; Universities Australia, 2019). Stephenson (2009) documented one case where an

Australian national teaching award was presented to a teacher on the basis of innovation, which included the introduction of Brain Gym®: a pseudoscientific (Tardif et al., 2015) and unproven program based on discredited theories related to learning (Hyatt, 2007; Spaulding et al., 2010). An alternative interpretation of the findings of Horvath et al. (2018) is simply that belief in neuromyths is endemic across the profession. Further, it remains possible that a belief in neuromyths, and subsequent application of neuromyth beliefs, could still be detrimental to the teaching of both award winning and non-award winning teachers.

Immunisation Against Neuromyths

It might be hoped that the provision of accurate knowledge about the brain, and about learning more broadly, would provide educators with "immunization" against belief in neuromyths. However, research examining the protective effects of education and neuroscience knowledge has been somewhat variable. For example, findings on the relationship between general brain knowledge and neuromyth belief has been inconsistent (see Dekker et al., 2012; Howard-Jones et al., 2009; Kim & Sankey, 2018). It might also be expected that educational background could provide a degree of immunisation against acceptance of neuromyths but factors such as degree level education, neuroscience course completion (Macdonald et al., 2017) and number of education courses completed (Ruhaak & Cook, 2018) appear to have only modest relationship with neuromyth belief. Thus, evidence of possible protective effects of knowledge and educational background on neuromyth belief is equivocal.

Sources of Information for Neuromyths

There has been considerable speculation as to how neuromyths arise. Neuromyths may arise from misinterpretation or oversimplification of legitimate scientific information (Alferink & Farmer-Dougan, 2010; Geake, 2008; Organisation for Economic Co-operation and Development, 2007), overgeneralisation or overinterpretation of scientific evidence (Alferink & Farmer-Dougan, 2010; Macdonald et al., 2017), problems related to communication of complex scientific ideas (Howard-Jones, 2014), wishful thinking on the part of practitioners (Howard-Jones, 2014), and the popular media (Ruhaak & Cook, 2018). Further, neuromyths may be linked to commercial interests (Organisation for Economic Co-operation and Development, 2007). Their propagation may therefore be systematic and deliberate. Given the speculative nature of discourse regarding the genesis of neuromyths, understanding of the sources of information reported by believers and non-believers of neuromyths may offer insights.

Some researchers have identified sources of information about neuroscience (Im et al., 2018) or the role of the brain in education (Rato et al., 2013) but not the sources for specific neuromyths (or conversely, correct neuromyth knowledge). While there is still relatively little data on the sources of information related to specific neuromyths, a number of possible sources of information leading to the acceptance of these myths have been suggested in recent papers. Among preservice special education teachers, for example, Ruhaak and Cook (2018) found that their participants did not feel their teacher education programs were providing adequate preparation to identify neuromyths. Perhaps for this reason, around 40% reported using popular press or online sources to obtain information on learning and the brain. Based on a small subsample of six participants who completed qualitative interviews, the researchers noted that "when interview participants were asked where and/or how they learned about the neuromyth-based practices they supported, many cited their classmates, mentor teachers, and *preparation programs*" (Ruhaak & Cook, 2018, p. 3, emphasis added).

Focusing on five neuromyths, Kim and Sankey (2018) investigated sources of belief of 358 first year education students (subset of a larger study) in an Australian university. Almost half reported their belief in learning styles instruction came from school teachers and 20.5% gave teachers as the source of their beliefs about left brain/right brain learning. Across all five beliefs, between 1.5% and 8.1% of students cited university lectures as a source. Thus, while there is relatively little data on the sources of information related to specific neuromyths, a number of possible sources of information leading to the acceptance of these myths have been suggested. These include the popular press, teacher educators, classroom mentors and the internet.

The Present Study

In the present study we examine the prevalence, predictors, and sources of belief and disbelief in neuromyths in a large sample of Australian pre-service teachers. While neuromyths have been examined in a range of countries, there is limited research in Australia. In addition, research on the effect of knowledge in providing a degree of immunisation to belief in neuromyths has been somewhat inconsistent. Further, there are limited data on the sources of information reported by believers and non-believers in neuromyths. Thus, the research questions for the current study were:

1. What is the extent of belief in neuromyths in an Australian sample of undergraduates enrolled in a teacher education program?
2. What factors predict neuromyth belief and disbelief (age, gender, degree of enrolment, number of units completed, completion of units addressing neuromyths, general brain knowledge)?
3. What sources of information do preservice teachers report related to their views on neuromyths?

Method

Ethical Approval

The research was approved by the institution's Human Research Ethics Committee and participants gave informed consent for their data to be used for research purposes.

Procedures

The data for this research was collected in a series of online surveys that were administered in mandatory units in undergraduate programs in teacher education at Macquarie University. The surveys were used to collect data required as part of registration of the teacher education programs and were also used for research purposes. Students were either awarded participation points for completing the surveys, or completing the surveys was a compulsory part of the unit. Once it was completed students could then elect to have their data for each survey made available for research purposes. Data used in the present study was collected across two surveys. An administrative officer deidentified surveys and generated a unique identifier for each response such that data in the surveys used could be matched, but the identity of the students was unknown to the researchers.

Survey

Basic demographic information on students was collected in the first survey including age, gender, degree enrolled and number of units completed (indicating typical completion rates for between 1 and 4 years of full-time equivalent study). Students also responded on a five-point Likert-type scale from Strongly Disagree to Strongly Agree to the following statement from the Preparedness for Teaching Scale (Mayer et al., 2015): “To date, my teacher education program has prepared me in the following areas: Know students and how they learn”. In addition, the first survey was used to collect data on student opinions on teaching and their preparation, which was not directly relevant to the current research.

In the second survey, information was collected on whether students had been or were currently enrolled in one of two units in which some neuromyths were explicitly addressed. These were a unit in early childhood, normally completed in first year, and a unit in the primary and secondary programs that was normally completed in the second year. Students were presented with a series of statements (15 neuromyths followed by 17 general brain knowledge statements) adapted from Dekker et al. (2012). Two neuromyth statements were changed as recommended by Macdonald et al. (2017) to reflect more current knowledge. Specifically, statements on the effect of caffeine on behaviour and fatty acid supplements were dropped and items related to the Mozart effect and dyslexia were added. In addition, the general brain knowledge statement “Learning is not due to the addition of new cells” was changed to “Learning is due to the addition of new cells” for clarity, consistent with Macdonald et al. (2017). Participants were required to respond to each statement by indicating whether they thought it was “Correct”, “Incorrect” or “Do not know”.

In the final part of the survey, students were asked about the sources of information for their responses. For students who indicated that a given statement was incorrect or correct, their decision was fed back and they were asked to identify the source of their knowledge. For example:

> *You indicated that the statement 'Individuals learn better when they receive information in their preferred learning style (e.g., auditory, visual, kinesthetic)' is <u>correct</u>. Please identify where you have learned about this. Select all that apply.*

The response options were: general knowledge; peer-reviewed journal articles; communication with teachers or school staff; communication with peers enrolled in my degree; communication with academic staff (tutorials, lectures etc); social media; television programs; websites.

When respondents indicated that they did not know whether a neuromyth statement was correct or not, their response was fed back and they were asked to indicate the basis of their choice. The response options were: I don’t have enough information about this to make a judgement; I have heard conflicting information about this; I have never heard of this before. Responses were mandatory for all sections of the survey, except the final part when students were presented with different options depending on their preceding answers.

Participants

At the commencement of the semester, a total of 2179 students were eligible to complete the surveys. Some students completed surveys more than once and only the first attempt was retained with duplicates eliminated. Eliminating incomplete surveys and duplicates, 1900 students completed the first survey (demographic data). Of these, 1836 consented for their data to be used for research purposes. Eliminating incomplete surveys and duplicates, a total of 1867 students completed the second survey (neuromyths and brain knowledge). Of these, 1496 consented for their data to be used for research purposes. Only students who completed both surveys and consented for their data to be used for both (N = 1359) were included in the analysis. The mean age of respondents was 22.7 years (*SD* = 5.7, range 17-59) and other demographic data for the sample are provided in Table 1.

	Characteristic	Number
Gender	Female	1101
	Male	251
	Other	7
Enrolled degree	Bachelor of Arts - Psychology with the degree of Bachelor of Education (Primary)	177
	Bachelor of Arts (Major in Education)	16
	Bachelor of Arts with the degree of Bachelor of Education (Primary)	397
	Bachelor of Arts with the degree of Bachelor of Education (Secondary)	242
	Bachelor of Education (Early Childhood Education) (Birth to 12)	206
	Bachelor of Education (Primary)	75
	Bachelor of Education (Secondary)	84
	Bachelor of Teaching (Early Childhood Education)	52
	Other	110
Number of units successfully completed	Less than 8 (typical of students in their first year of full-time study)	378
	8-16 (typical of students in their second year of full-time study)	366
	16-24 (typical of students in their third year of full-time study)	286
	24-32 (typical of a student in their fourth year of full-time study)	270
	More than 32	59

Table 1: Demographic characteristics

Analysis

Participant responses to each Neuromyth and Brain General Knowledge statement were categorised as accurate, inaccurate or do not know and percentages of the total number of responses calculated. Neuromyth and Brain General Knowledge scores were created by totalling the number of accurate responses by each respondent to each set of statements. A linear regression was conducted with score on Neuromyth beliefs as the dependent variable. The neuromyth survey could be completed at any point in the first 10 weeks of the semester, so it could not be determined if the relevant content in the target units (containing address of some neuromyths) had been covered prior to survey completion. Thus, students were classified into those that had previously completed each unit and those who were currently enrolled. Whether participants were currently enrolled in one of the target units (binary, yes or no), whether participants had previously completed one of the target units (binary, yes or no), total correct score on Brain General Knowledge, the number of units successfully completed to date, and total rating on students' perceptions of the extent to which their teacher education program had prepared them in regards to knowing students and how they learn, were entered as predictors. Age in years and gender were entered as control variables.

Sources of information reported by students who responded accurately to neuromyth statements were tallied and reported as a percentage of the total number of accurate responses. Corresponding data were calculated for inaccurate responders. Finally, the reasons nominated by students who responded to statements with "Do not know" were reported as a percentage of the total "Do not know" respondents.

Results

Data on responses to each of the neuromyth statements are provided in Table 2. The mean inaccurate responses to neuromyth statements was 37.2% (range 6.3%– 80.5%). More than half of the students accepted the statements that "environments that are rich in stimulus improve the brains of pre-school children" (80.5%), "individuals learn better when they receive information in their preferred learning style" (77.5%), "a common sign of dyslexia is seeing letters backwards" (59.4%), children are less attentive after consuming sugary drinks, and/or snacks" (58.0%), and "short bouts of co-ordination exercises can improve integration of left and right hemispheric brain function" (56.6%). The mean inaccurate responses across brain knowledge statements was 12.3% (range 2.4% - 58.4%) with a mean of 60.1% (range 11.9 % - 85.8%) of respondents accurate and a mean of 27.6% (11.8% - 42.8%) indicating "Do not know".

Descriptive statistics and frequencies of all variables are provided in Table 3. In addition to the currently enrolled and previously completed students, a further 380 students were neither currently enrolled nor had previously completed either of the target units at the time of the survey. Due to changes in degree program, 16 students were both currently enrolled and had previously completed one or more of the target units. Seven students selected "other" for gender.

The overall model was significant, $F(8, 1350) = 43.49$, $p < .001$, $R^2 = .20$. Table 4 gives bivariate Pearson correlations, raw and standardised regression coefficients and significance levels for each predictor. Note that gender was dummy coded such that males were the reference category. Gender comparisons are therefore female vs male and other vs male. Currently enrolled and previously completed are coded such that not being currently enrolled and not having previously completed target units are the reference categories for each variable respectively.

As seen in Table 3, being currently enrolled in a target unit, having previously completed a target unit, score on Brain General Knowledge and age all positively predicted Neuromyths score. It should be noted that being currently enrolled in a target unit was not related to Neuromyths score in the bivariate analyses, and only became significant when entered into the full regression model. Conversely, the number of units completed and the extent to which students felt their teacher education program had prepared them in regards to knowing students and how they learn were significant in the bivariate analyses, but became non-significant when entered into the full model. Of particular interest are the standardised beta coefficients, which indicate that score on Brain General Knowledge had the largest effect on Neuromyths score, followed by having previously completed one of the target units, and then being currently enrolled in one of the target units.

Sources of information for each neuromyth for both accurate and inaccurate responders is reported in Table 5. Differences of more than 15% between accurate and inaccurate responders are indicated by shading. Averaged across all statements, the most common sources of information for accurate responders was general knowledge (52.2%) and communication with academic staff (42.1%), with all other sources below 20%. For inaccurate responders, the most common sources reported were general knowledge (51.5%), communication with academic staff (39.2%) and communication with teachers or school staff (23.9%), with all other sources below 20%. Overall, the mean level of reported sources did not differ greatly for accurate and inaccurate responders with the largest overall difference being 7% for communication with teachers and schools. There were, however, some large differences for specific neuromyths. For example, for the myth related to improved learning with modality matched instruction, accurate responders were more likely to rely on academic staff (80.8% vs. 48.9%) and less likely to rely on communication with school staff (17% vs. 47.2%) or general knowledge (14.4% vs. 54.3%).

Reasons offered by students for “Do not know” responses are presented in Table 6. Over 50% of students reported that they did not have sufficient information to make a judgment for all statements, with one exception. For the statement regarding learning styles-based instruction, 62.3% reported receiving conflicting information.

		% Responses		
Neuromyth Statement	*C/I	Accurate	Inaccurate	Do Not Know
Individuals learn better when they receive information in their preferred learning style (e.g., auditory, visual, kinesthetic).	I	16.9	77.4	5.7
Differences in hemispheric dominance (left brain, right brain) can help explain individual differences amongst learners.	I	17.8	45.9	36.3
Short bouts of co-ordination exercises can improve integration of left and right hemispheric brain function.	I	5.1	56.6	38.3
Exercises that rehearse co-ordination of motor-perception skills can improve literacy skills.	I	7.7	49.3	43.0
Environments that are rich in stimulus improve the brains of pre-school children.	I	5.7	80.5	13.8
Children are less attentive after consuming sugary drinks, and/or snacks.	I	13.9	58.0	28.1
A common sign of dyslexia is seeing letters backwards	I	11.4	59.4	29.2
There are critical periods in childhood after which certain things can no longer be learned.	I	60.8	20.9	18.3
We only use about 10% of our brain.	I	45.2	27.0	27.8
Listening to classical music increases children's reasoning ability	I	19.5	24.0	56.5
Children must acquire their native language before a second language is learned. If they do not do so neither language will be fully acquired.	I	54.1	20.5	25.4
Learning problems associated with developmental differences in brain function cannot be remediated by education.	I	55.0	9.5	35.5
If pupils do not drink sufficient amounts of water (6-8 glasses a day) their brains shrink.	I	62.8	6.3	30.9
Extended rehearsal of some mental processes can change the shape and structure of some parts of the brain.	C	37.8	16.5	45.7
Individual learners show preferences for the mode in which they receive information (e.g., visual auditory, kinesthetic).	C	84.2	6.3	9.5
Mean		**33.2**	**37.2**	**29.6**
SD		**25.4**	**25.3**	**13.9**

* C = correct, I = incorrect

Table 2: Responses to neuromyth statements (N=1359)

	Mean (SD)	Range
Neuromyths score	4.98 (2.39)	0 – 15
Brain General Knowledge	10.21 (3.27)	0 – 17
Number of units completed	1.46 (1.21)	0 – 4
Extent of preparation	4.22 (0.81)	1 – 5
Age	22.72 (5.71)	17 – 59
	Frequencies	
Currently enrolled	Yes = 326	No = 1 033
Previously completed	Yes = 669	No = 690
Gender	Female = 1 101	Male = 251

Table 3: Descriptive statistics and frequencies of all variables entered into regressions

Predictor	Bivariate *r*	Regression coefficient	Standardised beta
Currently enrolled	-.02	.33*	.06
Previously completed	.13***	.61***	.13
Brain General Knowledge	.43***	.31***	.42
Number of units completed	.09**	.01	.004
Extent of preparation	.06*	.01	.002
Age	.11***	.02*	.05
Gender (Female vs male)	-.03	-.17	-.03
Gender (Other vs male)	.02	-.30	-.01

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 4: Bivariate Pearson correlations, raw and standardised regression coefficients and significance levels for predictors

	Inaccurate Responses %									Accurate Responses %								
	Number	General Knowledge	Peer-reviewed journal articles	Communication with teachers or school staff	Communication with peers enrolled in my degree	Communication with academic staff (tutorials, lectures etc)	Social media	Television Programs	Websites	Number	General Knowledge	Peer-reviewed journal articles	Communication with teachers or school staff	Communication with peers enrolled in my degree	Communication with academic staff (tutorials, lectures etc)	Social media	Television Programs	Websites
Individuals learn better when they receive information in their preferred learning style (e.g., auditory, visual, kinesthetic).	1049	54.3	26.8	47.2	29.7	48.9	10.4	7.9	17.8	229	14.4	24.5	17.0	15.7	80.8	3.1	2.2	7.0
Differences in hemispheric dominance (left brain, right brain) can help explain individual differences amongst learners.	620	44.7	19.5	23.9	18.9	37.4	8.9	9.4	19.5	239	34.7	11.7	10.5	12.6	57.3	4.6	4.2	12.6
Short bouts of co-ordination exercises can improve integration of left and right hemispheric brain function.	762	49.2	20.1	27.7	17.1	33.6	12.1	11.5	21.7	69	47.8	14.5	13.0	14.5	42.0	4.3	8.7	14.5
Exercises that rehearse co-ordination of motor-perception skills can improve literacy skills.	664	42.5	23.9	28.5	20.0	40.1	8.3	7.2	19.0	105	65.7	11.4	6.7	11.4	25.7	3.8	1.9	9.5
Environments that are rich in stimulus improve the brains of pre-school children.	1087	48.4	34.1	34.1	26.8	56.4	9.9	9.0	16.2	77	39.0	19.5	27.3	29.9	46.8	3.9	1.3	11.7
Children are less attentive after consuming sugary drinks, and/or snacks.	784	71.2	16.5	30.2	20.5	27.7	24.0	25.8	26.1	183	59.6	10.9	19.7	16.9	23.5	16.4	9.8	20.8
A common sign of dyslexia is seeing letters backwards	802	66.6	15.2	26.8	20.9	30.3	12.0	15.2	22.3	155	43.9	15.5	17.4	14.2	32.3	4.5	3.9	34.8
There are critical periods in childhood after which certain things can no longer be learned.	280	36.4	31.1	23.2	20.0	57.5	10.4	7.5	17.9	816	52.8	19.6	17.9	17.4	51.0	3.9	4.0	11.0
We only use about 10% of our brain.	364	62.4	10.4	15.4	13.2	35.4	17.9	19.5	22.0	611	56.1	20.9	14.6	16.7	46.5	13.7	16.0	28.5
Listening to classical music increases children's reasoning ability	325	54.2	20.3	26.5	20.6	31.4	21.5	20.3	25.5	261	69.0	6.5	8.4	8.4	17.2	6.5	6.1	16.9
Children must acquire their native language before a second language is learned. If they do not do so neither language will be fully acquired.	276	46.7	27.5	21.0	20.3	52.9	4.3	3.6	14.1	731	61.4	20.0	14.6	14.6	41.5	5.3	6.3	10.5
Learning problems associated with developmental differences in brain function cannot be remediated by education.	129	46.5	17.8	21.7	18.6	38.8	6.2	7.0	17.1	739	49.5	22.2	23.4	20.7	50.5	3.9	4.1	11.2
If pupils do not drink sufficient amounts of water (6-8 glasses a day) their brains shrink.	85	52.9	16.5	16.5	14.1	20.0	14.1	10.6	30.6	845	85.7	5.4	6.2	8.2	12.5	5.4	4.3	12.8

	Inaccurate Responses %									Accurate Responses %								
	Number	General Knowledge	Peer-reviewed journal articles	Communication with teachers or school staff	Communication with peers enrolled in my degree	Communication with academic staff (tutorials, lectures etc)	Social media	Television Programs	Websites	Number	General Knowledge	Peer-reviewed journal articles	Communication with teachers or school staff	Communication with peers enrolled in my degree	Communication with academic staff (tutorials, lectures etc)	Social media	Television Programs	Websites
Extended rehearsal of some mental processes can change the shape and structure of some parts of the brain.	222	65.3	3.6	3.2	3.6	16.7	0.5	1.4	5.9	512	45.7	24.2	17.0	13.9	52.1	4.9	5.7	17.4
Individual learners show preferences for the mode in which they receive information (e.g., visual auditory, kinesthetic).	86	31.4	12.8	12.8	14.0	60.5	1.2	3.5	9.3	1137	57.7	23.7	39.8	29.2	51.1	8.0	5.3	15.7
Mean		**51.5**	**19.7**	**23.9**	**18.6**	**39.2**	**10.8**	**10.6**	**19.0**		**52.2**	**16.7**	**16.9**	**16.3**	**42.1**	**6.2**	**5.6**	**15.7**
SD		**11.2**	**8.0**	**10.1**	**6.0**	**13.5**	**6.7**	**6.8**	**6.3**		**16.5**	**6.3**	**8.6**	**6.3**	**17.5**	**3.8**	**3.7**	**7.5**

Note: Sources where there was a 15 or greater percentage difference in favour of accurate responders are shaded dark grey. Sources where there was a 15 or greater percentage difference in favour of inaccurate responders are shaded light grey.

Table 5: Percent of inaccurate and accurate responders reporting each source of information

	Number	Percentage		
		I don't have enough information about this to make a judgement	I have heard conflicting information about this	I have never heard of this before
Individuals learn better when they receive information in their preferred learning style (e.g., auditory, visual, kinesthetic).	77	33.8	62.3	3.9
Differences in hemispheric dominance (left brain, right brain) can help explain individual differences amongst learners.	491	61.7	18.5	19.8
Short bouts of co-ordination exercises can improve integration of left and right hemispheric brain function.	520	62.1	7.7	30.2
Exercises that rehearse co-ordination of motor-perception skills can improve literacy skills.	582	56.7	7.2	36.1
Environments that are rich in stimulus improve the brains of pre-school children.	186	55.9	28.5	15.6
Children are less attentive after consuming sugary drinks, and/or snacks.	381	53.3	38.6	8.1
A common sign of dyslexia is seeing letters backwards	395	69.4	15.7	14.9
There are critical periods in childhood after which certain things can no longer be learned.	248	58.9	25.0	16.1
We only use about 10% of our brain.	375	57.6	25.1	17.3
Listening to classical music increases children's reasoning ability	764	52.7	25.4	21.9
Children must acquire their native language before a second language is learned. If they do not do so neither language will be fully acquired.	340	59.7	19.4	20.9
Learning problems associated with developmental differences in brain function cannot be remediated by education.	478	64.6	14.4	20.9
If pupils do not drink sufficient amounts of water (6-8 glasses a day) their brains shrink.	418	53.1	12.4	34.4
Extended rehearsal of some mental processes can change the shape and structure of some parts of the brain.	617	57.7	9.7	32.6
Individual learners show preferences for the mode in which they receive information (e.g., visual auditory, kinesthetic).	127	53.5	36.2	10.2

Table 6: Reasons given for "Do not know" responses

Discussion

The purpose of the present study was to examine the prevalence, predictors, and reported sources of information of neuromyths in a large sample of Australian pre-service teachers.

Neuromyth Belief

As in previous surveys of teachers and preservice teachers, most of which have been conducted in other countries, participants demonstrated broad agreement with several neuromyths. Five myths were believed by more than half the cohort, including that "environments that are rich in stimulus improve the brains of pre-school children" (80.5% inaccurate), "individuals learn better when they receive information in their preferred learning style" (77.4% inaccurate), "a common sign of dyslexia is seeing letters backwards" (59.4% inaccurate), "children are less attentive after consuming sugary drinks, and/or snacks" (58% inaccurate), and that "short bouts of co-ordination exercises can improve integration of left and right hemispheric brain function" (56.6% inaccurate). More positively, incorrect statements relating to critical periods, water consumption, and the remediation of learning problems associated with developmental differences were appropriately identified as inaccurate by more than half the sample. Overall, our findings show different levels of belief for different neuromyths, but suggest genuine reason for concern within Australia.

When individual neuromyths are considered, some consistency and some variation is seen between our findings and others. Consistent with our findings, for example, the myth that "environments that are rich in stimulus improve the brains of pre-school children" was also believed by over 80% of respondents in multiple previous studies (Dündar & Gündüz, 2016; Howard-Jones et al., 2009; Im et al., 2018; Kim & Sankey, 2018; Macdonald et al., 2017; Papadatou-Pastou et al., 2017). Similarly, although only one other study with preservice teachers (Papadatou-Pastou et al., 2017) has included an item related to letter reversals in dyslexia, a similar percentage of believers to ours (62.1%) was reported. However, there was more variation in responses regarding the effects of consumption of sugary drinks for which 58% of our respondents accepted as true. Although 64% of participants in Im et al. (2018) believed children became less attentive, only a third of the respondents in Papadatou-Pastou et al. (2017) believed this myth. Belief in the effects of exercise on hemispheric integration was also variable with Papadatou-Pastou et al. (2017) reporting 36.7% inaccurate and Kim and Sankey (2018) reporting 86.9% inaccurate, compared with our sample at 56.6% inaccurate.

Only one study to date has considered the neuromyth beliefs of Australian pre-service teachers. Interestingly, and despite the use of overlapping items, we found different rates of neuromyth prevalence. Relative to Kim and Sankey (2018), students in the current study had a lower level of incorrect belief overall with particularly large differences for belief in myths about learning styles instruction (77.4% versus 97.1% inaccurate) and hemispheric dominance (45.9% versus 86.0% inaccurate). It is possible that university experience plays a role in these differences, with the survey of Kim and Sankey (2018), limited to first year students. In the current study, however, units completed was not a predictor of accuracy in the full model.

The intractability of some neuromyths is further illustrated by the low numbers of preservice teachers choosing the "Do not know" option instead of indicating "Correct" or "Incorrect". Only 5.7% responded to the learning style instruction myth with "Do not know", for example. The confidence shown by our participants in their knowledge of learning styles instruction is consistent with existing research, with only a small percentage of preservice teachers choosing “Do not know” across studies (e.g., 0.8% in Yoon, 2018; 11% in Howard-Jones et al., 2009). As well as indicating the popularity of some neuromyths, these figures also suggest that preservice teachers may at times have unwarranted confidence in their judgements. Carter et al. (2015) also found that Australian preservice teachers had high levels of confidence in their judgements of the research support for educational practices, including practices for which there was little or no research support.

As noted earlier, belief in some neuromyths may result in wasted resources that could have been directed at the implementation of effective practices. Certainly, the widespread belief in learning styles instruction could lead to stereotyping of students and inappropriate teaching strategies (Scott, 2010). Neuromyths, such as the belief that letter reversals are characteristic of dyslexia, may delay diagnosis of students with reading difficulties who do not reverse letters, and lead to mistaken diagnoses for typically developing children who exhibit letter reversals in the early stages of literacy learning (Macdonald et al., 2017).

There are some beliefs that are unlikely to have major impacts on day-to-day teaching, such as only using 10% of the brain. Similarly, the myth that “environments that are rich in stimulus improve the brains of pre-school children” is likely to be relatively harmless, compared with other myths, particularly given that the inverse is true. That is, severely impoverished environments are detrimental to development (Beckett et al., 2006). Yet these beliefs should also be addressed as they, along with beliefs that do have potentially deleterious effect on teaching, are incompatible with teaching as an evidence-based endeavour. As members of the teaching profession, all educators must be informed decision-makers (Kim & Sankey, 2018).

Predictors

Respondents in the current study were more accurate in general knowledge about the brain than on the neuromyths scale. Mean accurate responses for brain knowledge was 60.1% compared with 33.2% accurate for the neuromyths. For our sample, the regression analysis confirmed that Brain General Knowledge predicted more accurate Neuromyth scores, but the effect was modest. The present finding was consistent with Howard-Jones et al.’s (2009) study of preservice teachers. It was, however, inconsistent with the studies of Dekker et al. (2012) predominately with practicing teachers, and Kim and Sankey (2018) with first year preservice teachers. While differences in participant groups and procedures may account for the inconsistent findings, it should be noted that the size of the effects were limited, regardless of the direction. Thus, it would appear that higher levels of general brain knowledge and acceptance of neuromyths can coexist.

Having previously completed a target unit that explicitly addressed some neuromyths also significantly predicted more accurate neuromyth beliefs, but the effects were again modest. The small effects are not unexpected given the inconsistent findings in existing research for interventions designed to address neuromyths (see Grospietsch & Mayer, 2018; Im et al., 2018; McMahon et al., 2019; Sparks, 2018) and it is possible that more sustained intervention is needed.

Sources

In the current study we extended past research by allowing students to report general knowledge as a source of their belief in different neuromyths. This extension was important, as beliefs and knowledge held in semantic memory sometimes cannot be tied to a particular source (Tulving, 1972). Students reported a wide range of sources for their knowledge about neuromyths, with general knowledge the most common source for most neuromyths, followed by communication with academic staff.

There were limited differences in the reported sources used by accurate and inaccurate responders to form their beliefs, but there were some noticeable patterns for individual statements. Encouragingly, pre-service teachers who answered accurately when presented with the learning styles instruction neuromyth were highly likely to report communication from university academics (e.g., in lectures or tutorials) as a source of their knowledge (80.8%). They were less likely to rely on teachers and school staff, or on general knowledge. Less encouraging was the fact that 48.9% of inaccurate responders also reported communication from academics as a source. Providing both groups were accurate at monitoring and reporting the source of their knowledge, this finding raises the possibility that conflicting information may have been offered in different university classes. Supporting this possibility, two thirds of the participants who responded “Do not know” to this myth reported having received conflicting information. This highlights the importance of presenting consistent and accurate information in teacher preparation programs.

Kim and Sankey (2018) examined reported sources for neuromyths in preservice teachers. In contrast to the present study, however, they forced a single selection from a range of choices that did not include a general knowledge option. Kim and Sankey (2018) reported that school teachers were the source of information for 47.8% of students with regard to learning styles instruction. This corresponded closely with our data for inaccurate responders (47.2%). Only 17.0% of accurate responders in the current study, however, cited communication with teachers as a source. Similarly, with regard to belief that hemispheric dominance explained learning, Kim and Sankey (2018) reported 20.5% of students cited school teachers as a source and this compared with 23.9% of inaccurate responders in the current study. However, only 10.5% of accurate responders in the current study relied on school staff as a source of information. Thus, accurate responders with regard to these neuromyths tended to rely more on academic sources in our study. Kim and Sankey (2018) reported a much lower percentage of students citing academic sources for neuromyths but this may be related to their forced choice format and the fact the study was limited to first year students.

Future Research

The extensive nomination of general knowledge as an information source suggests that participants could not always tie their knowledge of a statement to a particular source. Given this was the most commonly selected option, it would be worthwhile including it in future studies. The present study was cross-sectional in nature and gave limited insight into how understanding of brain development and neuromyths changes over time. Longitudinal studies have the potential to provide such information. While some have argued that misunderstanding of basic principles underlying learning and acceptance of empirically discredited approaches to teaching are not problematic for educational effectiveness (Horvath et al., 2018), this is not the majority view. There is evidence that only a proportion of educators who believe in interventions that are in fact ineffective, will apply these interventions in practice (Newton & Miah, 2017). Nevertheless, the impact of such misunderstandings on teaching in terms of wasted resources and inappropriate instruction largely remains speculative. Given the widespread acceptance of neuromyths, quantifying this impact is an important direction for future research. Finally, attempts to address widely accepted neuromyths in preservice teachers have met with inconsistent success. Developing strategies for effectively addressing neuromyths, particularly those with the potential to negatively impact on teaching and learning, stands as a priority for future research.

Limitations

Our study had four major limitations that must be considered when interpreting findings. First, data for the present study were collected in two surveys. The first was used to obtain demographic data, where only 3% of students declined for data to be used for research purposes. In contrast, approximately 20% of students declined to have data used for research purposes in the second survey, which assessed their knowledge of neuromyths and general brain knowledge. Apart from demographic data, the first survey was used to collect data on student opinions on teaching and their preparation. In the second survey, it was clear that student knowledge was being assessed and this may account for the differential rate of research consent. Second, we relied on self-report from respondents as to the sources of their knowledge about neuromyths. While respondents' abilities to accurately report these sources should not be systematically biased towards one source or another, there is nonetheless the potential for inadvertent errors among individuals in identifying where they originally encountered this information (Johnson, 1997). Thus, like all self-report measures, the percentages reported should be treated as estimates. Third, the completion of a unit, where some neuromyths were formally addressed, was included as a predictor in our analysis. However, it is possible that neuromyths were covered informally in other education units or in the optional units that students completed outside their education program. Finally, it should be remembered that the data presented are observational in nature and that associations identified are not necessarily causal.

Conclusion

Consistent with previous studies in the area, belief in neuromyths was widespread in the current sample of preservice teachers. General brain knowledge and completion of units of study that addressed a sample of neuromyths all positively predicted accurate neuromyth scores but effects were modest. General knowledge and communication with academic staff were the most commonly reported sources of information on neuromyth statements. Additional research is needed on the impact of misunderstanding by teachers of learning processes and approaches as well as strategies to counter these misunderstandings.

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