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Research paper

Tenacious educational neuromyths: Prevalence among teachers and an intervention

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ABSTRACT

Background: Several studies have revealed a common high prevalence of educational neuromyths among teachers from different countries. However, only one intervention aimed at reducing these beliefs among in-service teachers has been reported to date, and it was conducted in a non-naturalistic setting.
Procedure: In the present study, we administered a survey to measure the prevalence of common neuromyths in a large sample ($n = 807$) of primary and secondary teachers from 203 schools across Catalonia (Spain), and then we evaluated the impact that a 15-hour online course on neuroscience had on a sample of them as compared to a control group.
Main findings: Results showed an initial distribution of neuromyth beliefs similar to those of previous studies and a large effect of the intervention on reducing their prevalence shortly after the training and in the long term.
Conclusions: These findings provide evidence that an intervention addressed to in-service teachers that is low-cost and easy to implement can cast corrective effects that persist over time in neuromyth beliefs.

Since the end of the twentieth century, there has been an ever-increasing interest in transferring the science of how people learn to the classroom. On the one hand, the scientific community has focused its attention more and more on questions of educational relevance, progressively bringing its research to the real contexts of education [1–3]. On the other hand, the educational community has been very enthusiastic and excited about the possibility of supporting its practices on scientific evidence [4–6].

Nevertheless, the existent communicative distance between researchers and teachers [7–9] and the propagation of many so-called brain-based learning claims and commercial applications not grounded in rigorous research [7,10] has caused the rise of diverse pseudoscientific myths in schools, and, especially, the proliferation of neuromyths [11]. The term "neuromyth" was coined by neurosurgeon Alan Crockard in the 1980s to refer to ideas about the brain in medical culture that were not supported by neuroscience [12]. Similarly, educational neuromyths would be those oversimplifications, misunderstandings, or misinterpretations of scientific findings about the brain that have been applied to describe specific processes of learning and instruction, and that have eventually been translated into practical applications for the classroom with questionable efficacy. These misconceptions are frequently grounded on intuitive or naive ideas about how the brain works and are usually the product of distortions unintentionally enhanced by people's confirmation bias [13].

In 2002, the OECD published a report on neuroscience and education that alerted society of an increasing proliferation of so-called neuromyths and warned against its related risks [11]. In 2012, a group of researchers analyzed the prevalence of some of these neuromyths in a group of primary and secondary school teachers, specifically from the United Kingdom and the Netherlands [14]. The results showed that some neuromyths were extremely prevalent in the educational communities of those countries. Since then, similar studies have been conducted with trainee and in-service teachers in many countries across the world, including Portugal [15], Turkey [16], Greece [17,18], Slovenia [19], Italy [20], Switzerland [21], Germany [22], and Spain [23] in Europe; Chile [24–26], Argentina [24,27], Ecuador [28], Peru, and among other countries in Latin America [24]; UK [29–31]; Australia [29,32,33]; United States [30,34,35]; Canada [30,36], Morocco [37], Caribbean nation [38], or China [39,40]. The results in all these countries are very similar to those in the study of Dekker et al. [14] (see [23]

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for a comparison across countries). Specifically, in most of these studies the majority of pre-service and in-service teachers surveyed hold a large number of misconceptions about the brain.

The most commonly spread neuromyths among these teachers are: "individuals learn better when they receive information in their preferred learning style (e.g., auditory, visual, kinaesthetic)"; "environments that are rich in stimuli improve the brains of preschool children", and "differences in hemispheric dominance (left brain, right brain) can help explain individual differences among learners". Some neuromyths vary widely across countries, as is the case of "if pupils do not drink sufficient amounts of water (6–9 glasses a day) their brains will shrink". These differences might be due to diverse cultural disparities. For example, the prevalence of the neuromyth we have just referred to has been shown to be greater in countries where a commercial brain gymnastics program that endorsed this false idea has been widely adopted by schools [41].

The issues associated with the proliferation of educational neuromyths are evident. If teachers and educators hope to guide their educational practices by using scientific evidence, it is essential that they have reliable information. Neuromyths and other misconceptions about learning and the brain are misleading because they make teachers think that they are making decisions and taking actions grounded in scientific evidence, when in fact they are not. Although it has not been systematically quantified to date, the opportunity cost that this entails could be too high [6]. But it could be even worse when these decisions involve economic investments (several companies offer solutions based on these neuromyths) and, especially, when they may have a negative impact on learning [13].

In fact, not only could neuromyths lead teachers to adopt potentially ineffective methods that may seriously jeopardize the quality of their practice, but they can also turn them into vectors of these misconceptions among students [42]. That is, the students may develop incorrect ideas not only about how they learn, but also regarding the most efficient learning strategies they should adopt throughout their lives.

To make matters more complicated, misconceptions have long been proven to be highly resistant to change so that, once they are accepted, it is very difficult to abandon them [43,44]. Considering the inconveniences that neuromyths and other educational and psychological misconceptions might inflict on education, there is an urgent need to combat them among teachers [42].

Some previous studies have analyzed the effectiveness of training pre-service teachers and psychology students with respect to the persistence of neuromyths and other more general educational or psychological misconceptions (for a review, see [45]). Part of these interventions were aimed at directly debunking target misconceptions through refutation-style readings and lectures embedded in single sessions or (educational) psychology courses [42,46,47]. In general, the results showed that refutation style materials reduced belief in neuromyths in the short term and that the corrective effects persisted in the long term (but see [48]). Some other studies explored the impact of increasing neuroscience knowledge on improving professional practice, enhancing students' achievement, or relinquishing neuromyths [49]. Among these studies, Im and colleagues [50] tested the impact of an educational psychology course that was run over the course of one semester to improve neuroscience knowledge and reduce belief in neuromyths among pre-service teachers. Through readings and lectures, the course presented relevant content related to neuroscience, and two neuromyths were explicitly debunked. Three months after the intervention, the course had improved pre-service teachers' neuroscience literacy but had not contributed to reducing the belief in misconceptions about the brain. Similarly, McMahon and colleagues [31] designed a 90-minute workshop to challenge pre-service teachers' beliefs in neuromyths and improve their knowledge about research to become critical consumers of research-based practices. The workshop included reproductions of experiments and lectures on neuroscience-based content, the problem of neuromyths, and teaching strategies associated with them. The results showed that, eight months later, the intervention did not impact on the general knowledge of the brain and only produced a slight decrease of teacher belief in neuromyths. Finally, McCarthy and Frantz [51] designed an introductory psychology course that aimed to engage students through critical thinking and covered contents related to neuromyths and other psychological misconceptions, but without making specific reference to them. At the end of the course, students had changed their previously held misconceptions regarding most of the myths evaluated, and they reported that this shift in perception was still consistent one year later.

So far, only one study has been aimed at reducing neuromyths among in-service teachers [52]. In this study, the teacher sample was exposed to refutation texts with information about popular neuromyths, and the prevalence of misconceptions was measured immediately afterward and one month later. The results showed that refutation texts significantly reduced neuromyth beliefs in the short term, but not in the long term.

Given the potential consequences of teachers' beliefs in neuromyths, it seems imperative to extend the research directed to combat misconceptions about the brain to this population. While pre-service teachers' misconceptions may be addressed during their training to become teachers, in-service teachers would need supplementary interventions that they should feel motivated to participate in. In the present study, we evaluated the impact that a 15-hour online course on neuroscience in a naturalistic setting has on the persistence of neuromyths in primary and secondary in-service school teachers, both in the short term (at the end of the course) and in the long term (3 months later). The aim was to study the effectiveness that a typical and inexpensive training action can have on decreasing teachers' misconceptions about the brain and, in turn, on improving their general knowledge of this discipline, a fact which could contribute to helping them identify pseudoscientific information and practices that are not properly grounded in evidence.

With this purpose in mind, we conducted two studies. In the first one, we surveyed a large sample of primary and secondary school teachers from Catalonia (a north-eastern region of Spain) to analyze the prevalence of widespread neuromyths in that population. In the second study, we provided training (an online course) to a sample of those teachers, and then surveyed them again, as we had done before the intervention. This time, they were surveyed directly after the end of the course, and again after three months.

The research questions we wished to answer were: 1) What is the prevalence of neuromyths and other misconceptions about the brain among teachers in Catalonia, and what variables are related to that prevalence? 2) What is the effect of a simple and low-cost intervention, applied in a naturalistic setting, on this prevalence both in the short term and long term? Regarding the first question, addressed in study 1, we hypothesized that the results would resemble those reported by other studies that had used the same survey, especially those conducted by Ferrero et al. in Spain (whose sample included 5.6% of Catalan teachers) [23]. Regarding the second question, addressed in study 2, we expected a decrease in the prevalence of neuromyths in the first post-test after the training —especially those treated explicitly or laterally in the intervention—, but an important setback of the results in the second post-test, as commonly occurs with other types of misconceptions [43]. Our study also aims to critically reflect on the definition of the term "neuromyth".

Method

Study 1

Participants

Participants included 807 primary and secondary teachers from different public and charter schools in Catalonia (Spain). 642 (80%) were females and 165 (20%) were males. These percentages are quite close to the distribution of males and females in the total population of

school teachers in Catalonia [53]. The mean age of participants was 42.92 years (SD = 8.95; Mo= 39). Participants were primary school teachers ($n = 181$; 22%) and secondary school teachers ($n = 613$; 76%). The rest of the characteristics of the sample are described in Table 2.

Procedure

Teachers were contacted by sending invitations to 311 primary and secondary schools in Catalonia. After accepting the invitation, 203 schools were asked to forward the information about the study (only the information about the Study 1) to all their staff teachers. Those who chose to participate followed a link to the online survey, which was defined as a survey about "common educational misconceptions". Once they had read the terms and conditions regarding the participation in this research and provided their informed consent, 807 teachers completed the 15-min survey (pre-test) (Fig. 1).

Materials

The survey was divided in two parts. The first part contained 17 questions related to demographic and background information, including age, sex, academic degree (graduate, postgraduate, PhD), specialization, professional qualification (primary or secondary school teachers), years of experience, interest in the topic of neuroscience, previous experience in neuroscience and education training, and perception about whether the findings of neuroscience were valuable for their teaching practice. Furthermore, the survey included questions regarding reading habits related to general science or neuroscience topics. No personal data identifying the participants were collected by the researchers.

The second part of the survey consisted of 32 items developed by Dekker et al. [14] which were adapted into the Catalan language by following the ITC recommendations [54]. The original survey included a set of 12 educational neuromyths as defined by OECD [11], as well as 20 additional general statements about the brain that had not appeared in the original OECD report. All the original neuromyths were false statements about the brain, while the general knowledge questions comprised true and false statements. In addition, three new false statements about multiple intelligences, brain training, and psychomotricity benefits for reading skills, respectively (items 33, 34, and 35; Appendix 1) were included. The rationale for including these statements was that previous non-published surveys conducted by our team had identified a high prevalence of these false beliefs in Catalan schools. To answer these items, participants were asked to mark one of three options: *correct, incorrect*, or *do not know*.

Data analysis

In this first study, we use data from participants who fully completed the initial survey (pre-test). First, to describe the prevalence of neuromyths and other educational misconceptions in the sample, the percentages of correct answers for each item in the survey were calculated. Second, to examine which factors predicted survey results, a series of non-parametric mean differences tests (since the correct answers in the survey did not show a normal distribution) or bivariate indices relations (Pearson correlations) were conducted depending on the categorical or continuous nature scale of the demographic measure. The corresponding effect sizes were also calculated for each of these indices (r_{rb}, η_p^2, Cohen's d, and squared Pearson's r). In order to compare the results between this study and the one carried out by Ferrero et al. [23] in Spain, χ^2 and Phi (φ) were also calculated. The values of both samples were used as two categorical variables (correct and error). Phi coefficient was used as a measure of the effect size, i.e., as a percentage symmetry difference. Their value ranges between −1 and +1 (±1, maximum association; 0, independence between variables; positive values mean a higher proportion of correct answers in favor of Ferrero's study). For all analysis, a statistical significance threshold of $\alpha = 0.01$ was used. Finally, the Catalan subsample (5.6% of the total sample, $n = 16$) from Ferrero et al. [23] was analyzed to check whether or not it was different from the rest of the Spanish sample, and prevalence of the myth that children must acquire their native language before second language is learned was also measured in the Spanish subsample from monolingual regions used in the study by Ferrero et al. [23].

Study 2

Participants

At the end of the survey in Study 1, subjects were invited to participate in an online course on educational neuroscience, either at the end of the school year or at the beginning of the following school year (two months later). 655 (81.2%) teachers chose to participate in the first iteration of the course and 152 (18.8%) preferred the second iteration. The teachers who chose the second iteration were asked why, and most reported that they had already signed up to other courses for the end of the school year (online courses unrelated to neuroscience or psychology, as detailed in the next procedure section). This way, we had an experimental group (teachers in the first iteration) that would take the

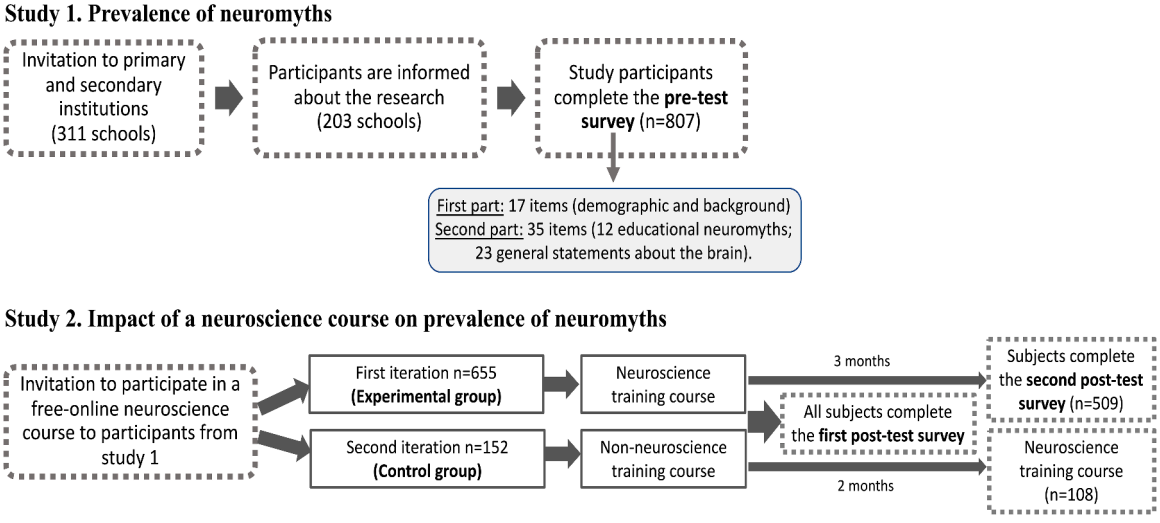


Fig. 1. Diagram of the experimental design.

neuroscience course before responding to the survey twice (right after completing the course and 3 months later), and a control group (teachers in the second iteration) that would respond to the second survey only once after finishing their courses unrelated to neuroscience and then take the neuroscience course at the end of the procedure. A total number of 515 (78.6% of 655) participants from the experimental group and 108 (71.1% of 152) from the control group finished the neuroscience course. All subjects from the control group completed the second survey. Among the participants in the experimental group, 6 were excluded from the second study because they did not complete the delayed survey that was carried out 3 months after the end of the course.

Procedure

All participant teachers read and signed a new document to provide their informed consent for the second study. Training for the experimental group consisted of a 15-hour asynchronous online course lasting one month. At the same time, teachers in the control group attended other professional development courses (all of which were online due to the COVID-19 pandemic). None of those courses were related to the fields of neuroscience or psychology (e.g., digital competence, teaching methodologies, evaluation, mediation). Once the experimental and control groups completed their courses, they answered the online post-survey (first post-test). In addition, the experimental group was asked to answer the post-survey again, 3 months after completing the neuroscience course (second post-test). 509 participants completed this last survey. Data analysis comprised data on 509 subjects from the experimental group who finished the course and completed the three surveys, and 108 subjects from the control group who not only completed two surveys, but also took the neuroscience course afterwards. This way, we were able to compare groups with a similar level of motivation in learning neuroscience (Fig. 1).

Materials

The surveys of the experimental group in the two post-test conditions (immediately after the intervention and 3 months later) were exactly the same, and they corresponded to the second part of the pre-test condition survey (as detailed in Study 1). The survey of the control group was identical to those of the experimental group, except that it also included questions about the type of course the participants took while the experimental group was taking the neuroscience course. The intervention consisted of a 15-hour online neuroscience course that included both content readings about brain development, functioning and structure, and some refutation texts aimed at debunking a number of neuromyths and other misconceptions. After each reading, participants had to answer three open-ended questions and five multiple-choice questions about the lesson's content. None of the multiple-choice questions resembled any of the items in the surveys. The neuroscience course provided explicit information related to 14 items (directly addressed) in the survey and laterally addressed (i.e., indirectly addressed) 7 items, but it did not cover content related to 14 items (not addressed). Explicit treatment consisted of correct explanations regarding general knowledge items, and refutation texts in the case of neuromyths. Not only did the refutation texts highlight the false statements, but they also provided an explanation for the origin of the neuromyths and an alternative interpretation of neuroscientific data. The laterally addressed items were not explicitly treated, but they could be easily inferred from the general neuroscience content of the course.

Data analysis

In this study, we only used data from the subjects that finished the course and completed all surveys, whether in the experimental group or in the control group. To analyze the effects of the intervention, we first compared the results of the pre-test against those of the first post-test regarding the following: (a) the whole survey, (b) the 12 neuromyth items, and (c) the rest of the general knowledge items, of both groups separately. Next, the same tests results were analyzed considering the level of treatment that the items had received, i.e., not addressed, indirectly addressed, or directly addressed.

To analyze the differences in means between the groups' performance (percentage of correct answers in the survey) before and after the intervention, repeated measures ANOVAs (with Bonferroni correction) and t-tests (paired and independent) were performed. We want to point out as a general consideration in the analyzes that whenever the variables did not pass the normality tests, we decided to calculate a more appropriate statistic than t or F (i.e., Mann–Whitney U, or Wilcoxon W) with their corresponding effect sizes.

Results

Study 1: prevalence of neuromyths and other misconceptions in the studied sample

Table 1 shows the items from our survey ordered according to the proportion of correct answers. On average, teachers scored 49.3% of correct answers across the whole survey. They agreed with 30.3% of the neuromyth items, and incorrectly answered 14.8% of the general knowledge items. A total of 15 items out of 35 (8 of them were considered neuromyths) had a success rate below 50% (i.e., less than 50% of participants answered them correctly). The items that received more incorrect answers corresponded to four neuromyths: (1) "environments that are rich in stimulus improve the brains of pre-school children" (90.0% incorrect answers); (2) "individuals learn better when they receive information in their preferred learning style (e.g., auditory, visual, kinesthetic)" (82.8%); (3) "short bouts of coordination exercises can improve integration of left and right hemispheric brain function" (82.7%); and (4) "exercises that rehearse coordination of motor-perception skills can improve literacy skills" (82.4%). In contrast, the items most successfully identified as neuromyths were (1) "learning problems associated with developmental differences in brain function cannot be remediated by education" (82,5% correct answers); (2) "children must acquire their native language before a second language is learned" (73%); (3) "if students do not drink sufficient amounts of water, their brains shrink" (63.6%); and "there are critical periods in childhood after which certain things can no longer be learned" (59.2%). The neuromyth that received the most "do not know" answers (49.3%) was "it has been scientifically proven that fatty acid supplements (omega-3 and omega-6) have a positive effect on academic achievement".

The items included in this survey as items 33, 34, and 35, which corresponded to brain misconceptions not identified by the OECD's original report as neuromyths, showed a very high prevalence. Only 1.1% of participants could recognize the statement claiming that reading skills are improved by psychomotricity exercises as false. On another note, only 20.2% and 25.1% of participants identified the false statements about memory training and multiple intelligences, respectively.

Table 1 also shows a comparison of this study with the one carried out by Ferrero et al. [23] in Spain. The contrast of proportion of correct answers between studies for each item of the survey revealed that, out of 32 possible comparisons, only two significant differences of medium size were found: one in favor of the Ferrero study group (item f22, $\varphi = 0.19$), and the other in favor of the group in this study (t20, $\varphi = -0.51$). We found other 6 significant differences, but the effect sizes were small or negligible, i.e., $\varphi = \pm 0.15$ or lower.

Variables related to the prevalence of neuromyths

Table 2 displays information regarding the demographic characteristics of the sample (data which was collected during the first part of the survey) and their relationship with neuromyth prevalence (the three

Table 1
Percentages (%) of correct and incorrect answers and comparisons with the study of Ferrero et al., (2016).

i	N	Content idea	Correct	Incorrect	DK	χ^2	*p*	φ
f25	**N**	**Coordination motor-perception**	**0.9**	**82.4**	**16.7**	9.64	.002	0.09
f30	**N**	**Coordination hemispheres**	**1.1**	**82.7**	**16.2**	0.69	.406	0.03
f35	*	**Reading motor exercises**	**1.1**	**63.1**	**35.8**			
f21	**N**	**Enriched environments**	**2.6**	**90.0**	**7.4**	0.04	.847	0.01
f09	**N**	**Dominant hemisphere**	**4.8**	**77.4**	**17.8**	10.40	.001	0.10
t03		**Boys bigger brain**	**7.2**	**68.3**	**24.5**	0.25	.614	0.02
f15	**N**	**Preferred learning style**	**7.2**	**82.8**	**10.0**	1.74	.188	−0.04
f05	**N**	**Omega 3, 6**	**11.6**	**39.1**	**49.3**	0.25	.620	−0.02
f22	**N**	**Attention and Sugar**	**11.8**	**62.3**	**26.0**	**40.34**	**< 0.001**	**0.19**
t08		**Hemispheres together**	**20.2**	**56.7**	**23.1**	0.21	.646	0.01
f33	*	**Memory training**	**20.2**	**57.7**	**22.2**			
f34	*	**Multiple intelligences**	**25.1**	**54.1**	**20.8**			
t06		**Damage brain**	**40.2**	**34.4**	**25.4**	8.12	.004	0.09
f07	**N**	**10% brain use**	**45.4**	**32.2**	**22.4**	13.96	< 0.001	−0.11
f10		**Brain same rhythm**	**47.3**	**23.5**	**29.2**	1.65	.199	0.04
t23		Circadian tiredness	50.6	13.6	35.8	17.53	< 0.001	−0.13
t24		Attention and caffeine	50.6	16.1	33.3	15.85	< 0.001	−0.12
t14		Learning new neurons	53.0	13.5	33.5	0.22	.637	−0.01
t18		Birth-death neurons	57.3	17.0	25.7	3.51	.061	0.06
t13		Network store	58.4	10.4	31.2	23.28	< 0.001	−0.15
f12	N	Critical periods learning	59.2	19.8	21.0	0.55	.455	−0.02
t26		Brain changes by repetition	61.3	6.7	32.1	2.51	.113	−0.05
t29		Age brain connections	62.6	13.2	24.1	23.71	< 0.001	0.15
f04	N	Water	63.6	7.9	28.5	0.10	.741	0.01
f02	N	Mother tongue	73.0	12.3	14.7	5.76	.016	0.07
t16		Neural connections	77.2	1.9	20.9	11.27	.001	−0.10
f28	N	Education and development	82.5	2.8	14.6	2.38	.123	−0.05
t17		Achievement breakfast	83.7	8.0	8.3	3.01	.083	−0.05
f11		Brain ends high school	84.4	3.2	12.4	3.17	.075	−0.05
t01		24 h brain use	88.7	4.3	6.9	5.46	.019	0.07
f19		Inherited intelligence	90.7	1.6	7.7	9.42	.002	0.09
t27		Information preference	92.6	2.0	5.4	0.30	.582	0.02
t31		Critical periods learning	94.2	0.6	5.2	18.87	< 0.001	−0.13
t20		Exercise improves brain	96.0	0.4	3.6	**280.03**	**< 0.001**	**−0.51**
f32		Sleep brain off	97.9	0.2	1.9	0.06	.815	0.01

Note. *i* = item; Items coded with an initial "t" (e.g., t01, t03…), correspond to true statements; Items with an initial "f" correspond to false statements; N: statements about the brain defined by the OECD as common neuromyths in education; DK = I do not know; Items are ordered according to ascending percentage of correct answers; Percentages in bold highlight items failed by more than 50% of the participants; φ = Phi coefficient as a measure of percentage symmetry difference (effect size); Positive side effects mean a higher proportion of correct answers in favor of Ferrero's study; Medium and large size differences between proportions are also highlighted in bold; * Items f33, f34 and f35 are not part of the original questionnaire, therefore their tests do not appear; $n = 807$; Ferrero et al., (2016) $n = 284$.

new items were not part of this analysis). Although most characteristics produced significant differences on neuromyth prevalence, the effect sizes were generally small; only reading neuroscience books and papers, reading scientific journals, having a scientific degree, or having a PhD degree yielded significant medium-sized differences (e.g., r_{rb} from 0.06 to 0.38). Interestingly, more years of professional experience did not yield substantive differences ($r_{rb} = 0.09$). Habits regarding reading of general press or reading pedagogical journals did not yield significant differences, either.

More general knowledge about neuroscience, as self-reported by the participants in the first part of the survey, predicted 5% of the correct answers of the whole survey ($r = 0.22$), or 6% of the 12 neuromyth items ($r = 0.26$). Furthermore, correlations between neuromyths and general knowledge items were low and statistically significant ($r(805) = 0.335$, $p < .001$).

Study 2: effect of an intervention on the prevalence of neuromyths and other misconceptions

Short-term effect of the intervention

A repeated measures ANOVA for both groups (control and experimental) revealed a significant linear within-subject effect attributable to the intervention, i.e., $F(1, 615) = 326.15$, $p = <.001$, $\eta_p^2 = 0.35$. Specifically, it revealed a significant effect of the interaction between the intervention and the two groups: $F(1, 615) = 204.78$, $p = <.001$, $\eta_p^2 = 0.25$. Control group pre-test mean was 0.45, post-test mean was 0.47; intervention group pre-test mean was 0.50, and post-test mean was 0.68. There was at least an average improvement of 25% in the survey results attributable to the intervention factor (controlling the group variable). When the pre-test means of the two groups were compared, there was a little difference in favor of the intervention group, which was nonetheless significant ($U = 19{,}549$, < 0.001, $r_{rb} = 0.29$).

The same trend of results was reproduced in the two subgroups of items as dependent variables (one with 12 neuromyth items, and the other with 23 general knowledge items). However, the effects of the intervention on neuromyth items were greater in magnitude ($\eta_p^2 = 0.33$) than on the rest of items ($\eta_p^2 = 0.05$).

Paired comparisons between all study conditions are shown in Table 4. All pre-test vs. first post-test differences were consistent in magnitude with the positive effect of the intervention, e.g., the biggest difference was found between the pre-test and the first post-test of the intervention group $W(13) = 1025$, $p < .001$, $r_{rb} = -0.98$. Effect sizes for control group comparisons were generally small or not significant (r_{rb} ranged from 0.02 to −0.44).

Long-term effect of the intervention

Another repeated measures ANOVA was performed, but this time adding one more measure (second post-test) and one more factor (the level of treatment for each item of the intervention, i.e., not addressed, indirectly addressed, or directly addressed). The analysis revealed a significant quadratic effect of the intervention in interaction with a linear effect of the level of treatment: $F(1, 508) = 80.74$, $p = <.001$, $\eta_p^2 = 0.35$. This means that although performance increased in the first

Table 2
Effects of sample characteristics on the total number of correct answers in the neuromyth items.

Variable	*n*	%	*Correct answers* *M*	*Statistic (gl)*	*p*	*Effect size*
Sex				U = 42,807	< 0.001	r_{rb} = 0.19
Male	165	20.4	0.55			
Female	642	79.6	0.52			
Education level				$F(2, 804)$ = 8.27	< 0.001	η_p^2 = 0.02
Degree[1]	475	58.9	0.51			
Master	270	33.5	0.54			
PhD[3]	62	7.7	0.57	t_{1-3} (804) = −3.68	< 0.001	d = −0.50
Science-based education				$F(3, 803)$ = 20.1	< 0.001	η_p^2 = 0.07
None[1]	366	45.4	0.49			
Technological[2]	65	8.1	0.53	t_{1-2} (803) = −2.61	0.045	d = −0.35
Experimental[3]	372	46.1	0.56	t_{1-3} (803) = −7.60	< 0.001	d = 0.56
Neuroscience	4	0.5	0.61			
Job				U = 35,187	< 0.001	r_{rb} = 0.37
Primary education teachers	181	22.4	0.47			
Secondary school teachers	613	76.0	0.54			
Professional experience				U = 73,796	0.026	r_{rb} = 0.09
< 10 years	380	47.2	0.53			
≥ 10 years	427	52.9	0.52			
Professional information			*yes-no*			
Scientific papers	75	9.3	0.58–0.52	U = 18,621	< 0.001	r_{rb} = 0.32
Pedagogical journals	155	19.2	0.52–0.53	U = 47,636	0.266	r_{rb} = 0.06
Scientific magazines	123	15.2	0.57–0.52	U = 30,984	< 0.001	r_{rb} = 0.26
Neuroscience books	137	17.0	0.59–0.51	U = 28,666	< 0.001	r_{rb} = 0.38
General press	519	64.3	0.53–0.52	U = 69,264	0.083	r_{rb} = 0.07
Neuroscience websites	149	18.5	0.55–0.52	U = 42,372	0.009	r_{rb} = 0.14
Utility of neuroscience	728	90.2	0.53–0.48	U = 22,443	< 0.001	r_{rb} = 0.22
Interest in neuroscience	807		3,1	$r(806)$ = 0.216	< 0.001	r^2 = 0.05

Note. U = Mann–Whitney U; r_{rb} = Rank biserial Correlation; η_p^2 = Partial η^2; d = Cohen's d; r = Pearson's r. Only significant post-hoc (t) comparisons are shown.

post-test compared to the pre-test, in the second post-test it declined as the items were addressed less explicitly. The intervened group substantially improved their scores in the first post measure, but their performance decreased moderately in the second post measure. Nevertheless, the results in the second post-test were significantly better than in the pre-test.

The paired tests showed that the pre-test measures were always significantly lower than both the first and second post measures. This improvement was even noticeable in scores that referred to items that were not addressed (medium effect size). However, the greatest differences were shown with respect to those items that were indirectly or directly addressed (with large effect sizes, $r_{rb} = -0.95$ to $r_{rb} = -0.97$).

The same trend of results was reproduced in the two subgroups of items (neuromyth items and general knowledge items). However, the effects of the intervention on neuromyth items were greater in magnitude (see Table 4 and Fig. 2).

Table 3 shows a summary of correct answers (%) for each item in each survey for both the control group and the intervention group. In the intervention group, items are organized according to the treatment level that they received in the neuroscience course, i.e., not addressed (A0), indirectly addressed (A1), or directly addressed (A2). The paired test differences between the performance means of the participants in each condition of Study 2 have been summarized in Table 4. Fig. 1 shows the results of the specific performance for neuromyth items.

Discussion

Several studies have provided evidence of a common high prevalence of educational neuromyths and other misconceptions about the brain among school teachers from all around the world. Regarding this issue, the results of Study 1, which analyzed the prevalence of misconceptions in a sample of Catalan school teachers, come as no surprise: they replicate the previous studies and, indeed, are very close to the results obtained by Ferrero et al. [23] with a population of Spanish teachers that included 5.6% of teachers from Catalonia. Compared to this study, only 8 out of 32 items yielded significant differences, and most of them had very small effect sizes ($\varphi = \pm 0.15$ or lower). The only difference that showed a remarkable effect size ($\varphi = -0.51$) corresponded to the item "vigorous exercise can improve mental function", which 96.0% of the Catalan sample identified correctly as true, while only 55.6% of the Spanish sample did.

Given this difference, we analyzed the data from Ferrero et al. [23] to check if their Catalan subsample (5.6% of the total sample, $n = 16$) could be different from the rest of the sample with respect to this item, but we did not find significant differences. Therefore, we assumed that either teacher knowledge regarding this idea has changed over the last few years, or the Catalan sample from Ferrero et al. [23] was too small to allow us to detect this difference when comparing Catalan teachers to teachers from other regions of Spain. In either case, we suggest that this difference may be explained by the fact that there was an educational program that became popular in Catalonia at the time, that was not in the rest of Spain (educational administrations of every region in Spain have a high degree of autonomy. Furthermore, many public and private educational initiatives kicking off in Catalonia stay local for linguistic and economic reasons). In any case, it would be interesting to analyze whether the frequencies of answers to this item have also changed in other regions of Spain since 2016, for the difference in the whole of Spain could then be attributable to some new program introduced at a national scale during the last few years. Our conjecture uses the same reasoning as Ferrero et al. [23] used to explain the significantly higher prevalence in the UK of the neuromyth stating that children's brains shrink if they don't drink enough water. Apparently, this myth was popularized by a commercial program (Brain Gym®) which was widespread in the UK [55]. However, in our case the same explanation is used to account for an increase in the prevalence of a correct idea about the brain (that vigorous exercise can improve mental function). Indeed, Dekker et al. [14] suggested that differences across countries in neuromyth prevalence may be related to differences in the marketing of brain-based programs. The same should be expected for the prevalence of items that are not neuromyths.

Catalonia is a highly bilingual region of Spain, where most of the population (>80%) speaks both Catalan and Spanish [57], and the education system uses Catalan as the lingua franca. For this reason, we further analyzed the myth that children must acquire their native language before a second language is learned and compared it to the results obtained by Ferrero et al. in 2016 [23]. The authors of this study already hypothesized that the prevalence of this neuromyth could be different in regions with just one official language compared to regions with several official languages, although they did not find significant differences in their sample. We didn't find any differences between the Catalan sample (12.3% of prevalence) of our study and the Spanish subsample from monolingual regions in the study by Ferrero et al. (9.3%). In addition, if we compare our results to those obtained in generally monolingual

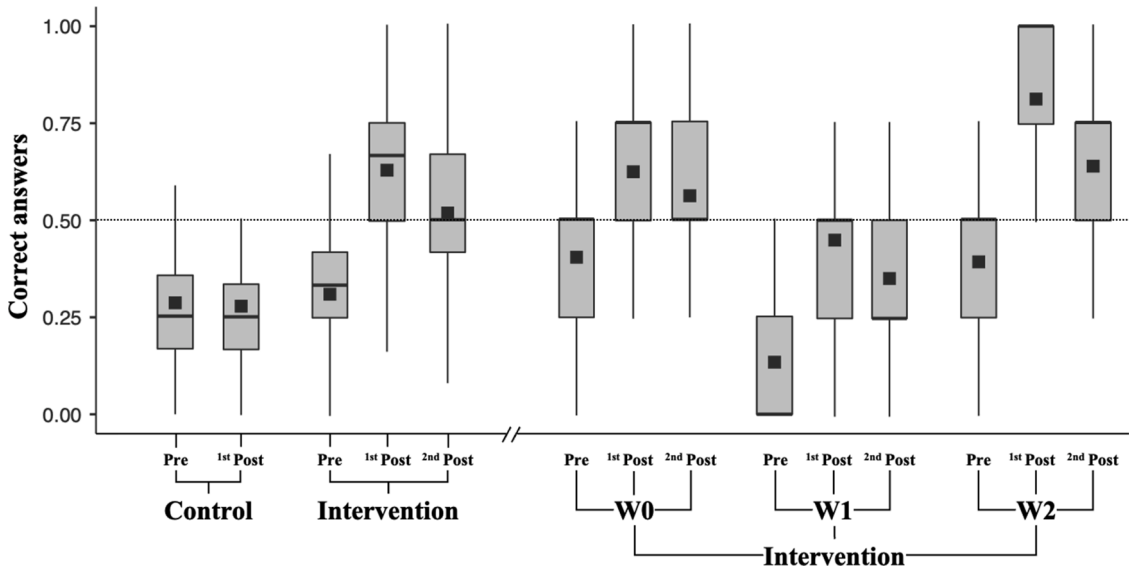


Fig. 2. Box plots of correct answers (%) in neuromyth items.
Note. Pre = pre-intervention measure; 1st Post = 1st measurement after intervention; 2nd Post = 2nd measurement after intervention; A0 = items not addressed in the intervention; A1= items indirectly addressed in the intervention; A2 = items directly addressed in the intervention. The square inside the box represents the mean of the data distribution; the line through the box represents the median of the data distribution. Intervention group n = 509; Control group n = 108.

countries, such as the UK (7%), Argentina (15.6%), Chile (19.7%), and Peru (50%), and in countries with a high degree of bilingualism, such as the Netherlands (36%), we do not find any pattern that relates the prevalence of this myth to the fact that the community is monolingual or bilingual.

Regarding the factors predicting the prevalence of neuromyths, teacher characteristics such as age or years of experience did not predict an increased belief in neuromyths or more general knowledge of the brain, while characteristics such as gender or reading scientific journals did. This was in line with the results from previous studies [14,23,24]. However, the most important predictors were type of education teachers had received and level of education they had achieved. In this regard, teachers who reported having graduated with a scientific (experimental) college degree (not including neuroscience) showed a medium effect size (d = 0.50) when compared to teachers who had not obtained a scientific degree at the university (excluding technological degrees). Since most of the teachers who reported having a higher degree (PhD or Master) had graduated with a scientific degree (88.7% of PhDs and 59.3% of Masters), the effect of studying science in college could help explain why higher degrees also showed significant differences of medium effect size as compared to lower degrees. However, a further analysis of the interactions between type of education and level of education could not statistically confirm this hypothesis because of the difference in the sample sizes.

Similarly, a difference was found between teachers working in primary and secondary schools. This could be explained by the fact that primary school teachers in Spain usually have one degree in education only, whereas secondary school teachers usually have degrees in other disciplines, including scientific degrees such as Biology, Chemistry, or Physics. In our sample, 2.0% of primary school teachers had a scientific degree, while the proportion of teachers with a scientific degree reached 52.1%. With this in mind, we analyzed if the differences in the survey between primary and secondary school teachers could be explained by differences in their college education (i.e., whether they received a scientific education or not), but the statistical analysis did not confirm our suspicions after controlling for this variable.

Overall, our results confirmed that there is widespread interest among teachers in the application of neuroscientific findings in educational practice [56,58]. Our initial sample consisted of 807 teachers who voluntarily agreed to fill in a survey about “common educational misconceptions”. However, not only did they report to have an interest in applying neuroscience to education (83.1% of the initial sample reported having a high or very high interest), but they also agreed to participate in a 15-hour educational neuroscience course, which was completed by 77.2% of the teachers. Other studies (e.g., [14]) have restricted their surveys to teachers who were already interested in neuroscience, and so the number of teachers from the general population who believe this type of science can support their practice could not be estimated. Indeed, 90.5% participants of our sample agreed that neuroscience could be useful to support educational decisions. Significantly, the degree of interest in this science predicted 5% of the correct answers of the survey.

In previous studies with in-service teachers, a higher incidence of neuromyths was predicted by better general knowledge of the brain, i.e., the more valid general knowledge about the brain was held, the more neuromyths were endorsed by in-service teachers [14,20,23,24,38,59]. Actually, in a recent review of interventions to dispel neuromyths in educational settings, Rousseau [45] stated that this finding "is probably the most robust pattern in the literature on neuromyths". This said, we have found a negative correlation in our study, i.e., the more valid general knowledge about the brain is held, the less neuromyths are endorsed by in-service teachers. This correlation was low but statistically significant, both for the experimental group ($r(507) = 0.319$, $p < .001$) and for the control group ($r(106) = 0.269$, $p < .001$). Although this contradicts the results of previous surveys conducted with in-service teachers, the result is still similar to those obtained in most surveys conducted with pre-service teachers [18,32,60,61] (but see [33]). We believe that heterogeneity in the results could be explained by the fact that teacher knowledge about neuroscience tends to be low and not too different from one another to become a relevant variable in predicting belief in specific neuromyths. In addition, the questionnaire adopted from Dekker et al. [14] may not be an appropriate instrument to estimate differences in knowledge of neuroscience among teachers. In this regard, Horvath et al. [29] performed a factor analysis of the test and found no underlying structure (i.e., items that did not coalesce into any distinct categories). In light of this, we agree with their recommendation that studies using this questionnaire should be interpreted cautiously (including this one), and that future studies on this topic should contemplate designing and validating a new test with an underlying construct validity.

Table 3
Percentages (%) of correct answers in Study 2.

		Intervention									Control	
		Pre			Post 1			Post 2			Pre	Post
#	Item content	A0	A1	A2	A0	A1	A2	A0	A1	A2	All	All
t03	Boys bigger brain	.08			.09			.13			.06	.10
f05	**Omega 3, 6**	**.12**			**.46**			**.38**			**.10**	**.09**
f22	**Attention and Sugar**	**.12**			**.25**			**.18**			**.16**	**.11**
t06	Damage brain	.43			.40			.47			.25	.27
f10	Brain same rhythm	.49			.37			.45			.44	.47
t24	Attention and caffeine	.52			.58			.59			.46	.56
t23	Circadian tiredness	.53			.63			.74			.37	.45
t18	Birth-death neurons	.56			.60			.70			.57	.65
t13	Network store	.60			.72			.78			.47	.52
f04	**Water**	**.64**			**.91**			**.84**			**.62**	**.69**
f02	**Mother tongue**	**.74**			**.88**			**.85**			**.66**	**.70**
t17	Achievement breakfast	.84			.80			.77			.76	.79
t01	24 h brain use	.90			.99			.95			.83	.88
f32	Sleep brain off	.98			1.00			.99			.99	1.00
f25	**Coordination moto-percept.**		**.00**			**.21**			**.15**		**.02**	**.00**
f30	**Coordination hemispheres**		**.01**			**.20**			**.15**		**.02**	**.02**
f09	**Dominant hemisphere**		**.05**			**.50**			**.33**		**.05**	**.02**
t08	Hemispheres together		.19			.67			.53		.19	.19
f07	**10% brain use**		**.47**			**.89**			**.78**		**.41**	**.37**
t14	Learning new neurons		.59			.78			.75		.28	.49
f11	Brain ends high school		.87			.92			.92		.76	.75
f35	*Reading motor exercises*			*.01*			*.27*			*.17*	*.01*	*.01*
f21	**Early stimuli**			**.03**			**.67**			**.40**	**.03**	**.03**
f15	**Preferred learning style**			**.07**			**.82**			**.58**	**.07**	**.05**
f33	*Memory training*			*.20*			*.50*			*.40*	*.29*	*.30*
f34	*Multiple intelligences*			*.22*			*.90*			*.72*	*.32*	*.28*
f12	**Critical periods learning**			**.61**			**.90**			**.75**	**.54**	**.52**
t29	Age brain connections			.64			.87			.81	.49	.56
t26	Repetition brain change			.65			.70			.68	.42	.38
t16	Neural connections			.78			.94			.94	.67	.73
f28	**Education and development**			**.86**			**.87**			**.83**	**.74**	**.73**
f19	Inherited intelligence			.93			.89			.89	.86	.89
t27	Information preference			.93			.63			.79	.89	.89
t31	Critical periods learning			.94			.98			.98	.96	.96
t20	Exercise improves brain			.97			.94			.94	.92	.96
Total	Whole Survey	.54	.31	.56	.62	.60	.78	.63	.52	.71	.45	.47
Total	General knowledge	.59	.55	.63	.62	.79	.76	.66	.73	.73	.53	.57
Total	**Neuromyths**	**.41**	**.13**	**.39**	**.63**	**.45**	**.82**	**.56**	**.35**	**.64**	**.29**	**.28**

Note. Pre = Prior measurement to intervention; Post 1 = 1st measurement after intervention; Post 2 = 2nd measurement after intervention; A0 = Not addressed in the intervention; A1 = Indirectly addressed in the intervention; A2 = Directly addressed in the intervention; Items coded with an initial "t" (e.g., t01, t03…), correspond to true statements; Items with an initial "f" correspond to false statements; Items in bold correspond to neuromyths; new added items in italics; Items are ordered according to ascending percentage of correct answers and level of inclusion in the intervention; Intervention group $n = 509$; Control group $n = 108$.

Most of the misconceptions that the OECD's report identified as neuromyths have indeed high prevalence, while others do not. In addition, other misconceptions that comply with the OECD definition of "neuromyth" but that were not labeled as such have very high prevalence, too. In fact, some items in the original survey that were labeled as general knowledge items could have been labeled as neuromyths. For example, denying that "the left and right hemisphere of the brain always work together", which was only identified as true by 20.2% of our sample, could be considered as a neuromyth, especially if we take into account that some educational programs offered to schools are based on the deceptive claim that the brain hemispheres work separately.

In addition, we included 3 new items in the survey that clearly yielded very high prevalence, too. These items are related to the notion of multiple intelligences, the idea that memory can be trained as a general ability, and the claim that psychomotricity exercises enhance reading skills. Not only are these false beliefs widespread, but they have been widely adopted by many schools and teachers to guide their practices [62,63] despite not being grounded in sound research. In fact, we drew on our personal experience and previous non-published surveys to hypothesize that the presumed effects of psychomotricity on cognitive development would be widely popular in Catalonia. This prediction was confirmed by the fact that only 1.1% of the teachers in our sample were able to detect the false claim that psychomotricity exercises improve reading skills. It would be very interesting if future studies could analyze the prevalence of these beliefs in other countries, and also identify other highly prevalent misconceptions about the brain and the mind that influence actual educational practices. Widespread educational neuromyths must be identified and dispelled because they waste time, money, and effort, which could be better spent on the application of evidence-based practices [64]. What is more, neuromyths may impact teacher motivation and affect their trust in a successful collaboration between science and education.

Regarding this matter, we would like to propose that the term "neuromyth" in education should be reserved for misconceptions about the brain that not only misguide educational decisions made by the members of the educational community, but that are highly prevalent among them. The OECD report defined neuromyth as a "misconception generated by a misunderstanding, a misreading, or a misquoting of facts scientifically established (by brain research) to make a case for use of brain research in education and other contexts" ([11], pp. 111). We think that this definition does not capture the notion that myths are regarded as widely held (but false) beliefs, and that precisely their high prevalence is what makes them a concern for education. With that in mind, some items from the original neuromyth survey should not be labeled as neuromyths because they are very infrequent. That would be the case of the item "if pupils do not drink sufficient amounts of water (=6–8 glasses a day) their brains will shrink", which has a low level of prevalence in all countries ($M = 13.23$, according to the meta-analysis

Table 4
Paired samples *t*-test of the correct answers in the survey according to how educational items were addressed during the intervention.

i	Group	Time	Focus	*M*	*SD*	*Statistic (tied pairs)*			*p*	*Effect size*
Whole survey	C	0	All	.45	0.11	W_{0-1} (*16*)	=	1508	0.014	$r_{rb} = -.295$
		1	All	.47	0.10					
	I	0	All	.50	0.11	W_{0-1} (*13*)	=	1025	< 0.001	$r_{rb} = -.983$
		1	All	.68	0.10	W_{1-2} (*77*)	=	72,406	< 0.001	$r_{rb} = 0.548$
		2	All	.64	0.11	W_{0-2} (*34*)	=	3597	< 0.001	$r_{rb} = -.936$
		0	0	.54	0.14	W_{0-1} (*75*)	=	18,108	< 0.001	$r_{rb} = -.616$
		1	0	.62	0.12	W_{1-2} (*121*)	=	33,206	0.039	$r_{rb} = -.120$
		2	0	.63	0.12	W_{0-2} (*86*)	=	14,806	< 0.001	$r_{rb} = -.670$
		0	1	.38	0.18	W_{0-1} (*76*)	=	2261	< 0.001	$r_{rb} = -.952$
		1	1	.60	0.21	W_{1-2} (*173*)	=	45,024	< 0.001	$r_{rb} = 0.590$
		2	1	.52	0.21	W_{0-2} (*126*)	=	8169	< 0.001	$r_{rb} = -.778$
		0	2	.56	0.12	W_{0-1} (*36*)	=	1621	< 0.001	$r_{rb} = -.971$
		1	2	.78	0.12	W_{1-2} (*110*)	=	6836	< 0.001	$r_{rb} = 0.606$
		2	2	.71	0.15	W_{0-2} (*64*)	=	6440	< 0.001	$r_{rb} = -.862$
Neuromyths	C	0	All	.28	0.15	W_{0-1} (*30*)	=	1571	0.883	$r_{rb} = 0.020$
		1	All	.28	0.13					
	I	0	All	.31	0.13	W_{0-1} (*17*)	=	963	< 0.001	$r_{rb} = -.984$
		1	All	.63	0.17	W_{1-2} (*107*)	=	72,400	< 0.001	$r_{rb} = 0.788$
		2	All	.52	0.19	W_{0-2} (*50*)	=	4437	< 0.001	$r_{rb} = -.916$
		0	0	.40	0.22	W_{0-1} (*154*)	=	5012	< 0.001	$r_{rb} = -.841$
		1	0	.62	0.23	W_{1-2} (*246*)	=	24,363	< 0.001	$r_{rb} = 0.404$
		2	0	.56	0.24	W_{0-2} (*181*)	=	7929	< 0.001	$r_{rb} = -.706$
		0	1	.13	0.15	W_{0-1} (*117*)	=	1000	< 0.001	$r_{rb} = -.974$
		1	1	.45	0.26	W_{1-2} (*230*)	=	30,982	< 0.001	$r_{rb} = 0.586$
		2	1	.35	0.25	W_{0-2} (*177*)	=	2428	< 0.001	$r_{rb} = -.912$
		0	2	.39	0.18	W_{0-1} (*63*)	=	1199	< 0.001	$r_{rb} = -.976$
		1	2	.81	0.23	W_{1-2} (*197*)	=	44,121	< 0.001	$r_{rb} = 0.807$
		2	2	.64	0.27	W_{0-2} (*137*)	=	5437	< 0.001	$r_{rb} = -.843$
General knowledge	C	0	All	.53	0.13	W_{0-1} (*18*)	=	1155	< 0.001	$r_{rb} = -.436$
		1	All	.57	0.13					
	I	0	All	.60	0.13	W_{0-1} (*61*)	=	8658	< 0.001	$r_{rb} = -.828$
		1	All	.70	0.09	W_{1-2} (*108*)	=	41,910	0.486	$r_{rb} = 0.040$
		2	All	.70	0.11	W_{0-2} (*60*)	=	10,553	< 0.001	$r_{rb} = -.791$
		0	0	.59	0.17	W_{0-1} (*120*)	=	31,229	0.002	$r_{rb} = -.177$
		1	0	.62	0.15	W_{1-2} (*159*)	=	19,640	< 0.001	$r_{rb} = -.361$
		2	0	.66	0.15	W_{0-2} (*125*)	=	21,363	< 0.001	$r_{rb} = -.422$
		0	1	.55	0.26	W_{0-1} (*168*)	=	3748	< 0.001	$r_{rb} = -.871$
		1	1	.79	0.24	W_{1-2} (*194*)	=	15,579	< 0.001	$r_{rb} = 0.342$
		2	1	.73	0.27	W_{0-2} (*185*)	=	6314	< 0.001	$r_{rb} = -.760$
		0	2	.63	0.14	W_{0-1} (*89*)	=	6982	< 0.001	$r_{rb} = -.842$
		1	2	.76	0.12	W_{1-2} (*162*)	=	38,575	< 0.001	$r_{rb} = 0.278$
		2	2	.74	0.14	W_{0-2} (*110*)	=	10,668	< 0.001	$r_{rb} = -.733$

Note. i = items; Neuromyth items: f02, f04, f05, f07, f09, f12, f15, f21, f22, f25, f28, f30; Misconception items: all other; C = Control group; I = Intervention group; Time = Measurement time (0 = pre, 1 = 1st post, 2 = 2nd post); Focus = intervention focus level (0 = not addressed, 1 = indirectly addressed, 2 = directly addressed); W = Wilcoxon W; r_{rb} = Rank biserial correlation; Intervention group n = 509; Control group n = 108.

performed by Ferrero et al. [23]). Likewise, some items labeled in the survey as general knowledge questions, which are frequently answered incorrectly by teachers, could be considered neuromyths provided that they misinform educational practice. Similarly, if new items are to be added to the list of neuromyths, we suggest that their prevalence should be taken into account first. That is the case of the new items we included in our study, which we suggest should be labeled as neuromyths.

Of course, this revised definition of neuromyth presupposes that a misconception that is thought to be a neuromyth in a specific educational community (e.g., a country) may not be so in another community due to differences in its prevalence [64]. In this regard, fighting against neuromyths would mean decreasing their prevalence to levels that do not represent a concern anymore. Therefore, it would be useful to achieve an agreement about what levels of prevalence would differentiate a brain misconception that may misguide educational practice from a neuromyth that represents a real concern.

It is also important to stress that misconceptions about the brain should be considered as neuromyths only if they could plausibly influence teachers' educational decisions. After all, a false belief about the brain that has no consequences in educational practice is just an anecdote, even if it is very prevalent. This implies that ideas labeled as neuromyths in the original survey, such as "children are less attentive after consuming sugary drinks and/or snacks", may have to be relabeled since they do not affect relevant educational decisions. Indeed, if believed to be true, which is not, this item would not have negative consequences at all [65].

On some occasions, the problem with certain beliefs about the brain is not that they are false. Correct facts about the brain can also be misleading. This happens when there is a lack of general knowledge about neuroscience and the facts are wrongly interpreted as evidence that supports other claims. For example, items about the differences between the brains of boys and girls (e.g., boys have bigger brains than girls and the brains of boys and girls [do not] develop at the same rate) are recurrently used to support single-sex education, although this type of differences cannot explain alleged differences in the effectiveness of this practice when compared to mixed education. Therefore, to redress the consequences of believing in neuromyths we probably need an intervention that not only refutes these claims, but also provides some general knowledge about neuroscience that allows educators to better evaluate the coherence of further interpretations that can be made from facts about the brain.

Some researchers have questioned the negative impact that holding beliefs in neuromyths may have on teacher effectiveness. For example, Horvath et al. [29] reported that the prevalence of neuromyth beliefs among a group of award-winning teachers was very close to that previously found among non-award-winning teachers, and concluded that this fact suggests that neuromyth beliefs are irrelevant to teacher effectiveness. However, this conclusion is questionable, since the fact that award-winning teachers hold the same amount of neuromyth beliefs than other teachers only proves that, in a situation where neuromyths are widely held by teachers, other differences among these teachers and their contexts may account for their differences in effectiveness. Furthermore, whether teaching awards are an appropriate measure of teacher effectiveness should be evaluated in the first place. In any case, although there is not enough causal evidence that supports the assumption that endorsing neuromyths has harmful effects on teaching practices and students' academic achievements [66], some educational policies are already being guided by neuromyths, and this leads to inappropriate spending of money and resources [45].

To decrease the prevalence of neuromyths and other brain misconceptions in education and prevent their proliferation, some researchers have suggested enhancing the neuroscience literacy of teachers and practitioners by explicit instruction. This instruction should particularly focus on dispelling neuromyths and revealing the lack of scientific evidence for many "brain-based" programs [45], but also on getting teachers to learn about specific themes of basic neuroscience [67]. In Study 2, we have analyzed the effects of a naturalistic intervention that consisted of a 15-hour online course on neuroscience. The course included cognitive neuroscience content readings about the brain's development, functioning and structure, and some refutation texts focused on debunking a number of neuromyths and other misconceptions, plus two of the new items we had incorporated into the survey (multiple intelligences and memory training). We deliberately created a course that was inexpensive to develop and easy to escalate, while keeping it within the standards of other training courses that teachers take in Spain. As a matter of fact, the Catalan Education Administration approved our course as an officially validated professional development activity for teachers. This allowed us to conduct this intervention in a naturalistic setting and analyze its effects assuming a considerable ecological validity. A limitation of our study design that is worth noting is the difference in sample sizes between the control group and the intervention group with respect to the analysis of variance. Although this difference may entail some issues (e.g., reduced statistical power, unequal variance, non-normality), we redressed them by (a) creating boxplots of neuromyth hits for each group and condition to show the reader of the manuscript the distribution of the values, and (b) applying nonparametric analysis based on the distribution of the data. We consider the results of the analysis of variance carried out to be robust. In fact, other studies have analyzed the robustness of these analyses under similar circumstances [68].

Our initial hypothesis predicted a decrease in the prevalence of neuromyths in the post-test done right after the intervention, and that this would be particularly noticeable in the items that were addressed directly. Indeed, the survey scores of the post measure were higher in the intervention group ($\eta_p^2 = 0.25$). This means that we can attribute a 25% increase in the number of correct answers in the first post-test to the intervention used. As for the neuromyth items (which included the three items we had devised for this study), the increase was higher ($\eta_p^2 = 0.33$).

However, measures immediately after an educational intervention must be taken cautiously. It is common to see all types of misconceptions coming back as time goes by, since the mechanisms of forgetting act upon what was learnt during the intervention [43]. Therefore, we expected the scores to be worse in the second post survey, which was conducted three months after the end of the intervention. The question was how dramatic the setback would be, and also what long-term effects of the intervention would persist, if any. To our knowledge, the only study to date that had aimed at reducing neuromyths among in-service teachers [48] revealed that an intervention based on refutation texts significantly reduced neuromyth beliefs in the short term, but not in the long term (1 month after the intervention). Therefore, this was one of the main questions we wanted to answer through our study. Eventually, the results of the second survey were worse (a quadratic model with a $\eta_p^2 = 0.35$) than those of the first survey, but they were still better than those of the pre-survey. In other words, although results in the long term were worse than in the short term, the effects of the intervention persisted in the long term with a high effect size ($r_{rb} = -.936$).

When looking at the effects on neuromyth prevalence according to the level of treatment that the neuromyths were given during the intervention (none, indirect, or direct), a surprising fact is that prevalence decreased in all cases, even for those which were not addressed in the course. Obviously, the items that had been addressed showed the greatest improvements, but there was still a statistically significant effect on those that had not been addressed. This effect was small and probably derived from a general impact of the intervention on enhancing a critical attitude on the part of the teacher with regard to the survey, especially after they realize that some items they previously assumed as true in the pre-test were debunked during the intervention.

Overall, we suggest that the long-term effects of our intervention could be explained by the fact that the intervention did not just provide teachers with isolated refutation texts or basic neuroscience content, but that it combined both. In other words, refutation texts were embedded in a course of general neuroscience, which probably provided a better semantic structure for teachers to understand and remember what they learned. In light of this, we recommend that professional development courses for teachers aiming to dispel neuromyths should include general neuroscience content combined with refutation texts where applicable.

As a side note, it must be pointed out that, after the intervention, there was an important decrease in the number of correct answers for item t27 ("individual learners show preferences for the mode in which they receive information"). Participants may have thought that the item referred to the myth of learning styles, one of the misconceptions that was explicitly addressed in the intervention. However, this item is actually one of the "kernels of truth" underlying the myth of learning styles (i.e., people show preferences when learning, but this does not mean that their preferences are the most effective ways to learn).

Conclusion

This study provides evidence for the development of an intervention with in-service primary and secondary school teachers that is both inexpensive and easily scalable and that can significantly contribute to reducing beliefs in neuromyths and other misconceptions about the brain. This action should help teachers and schools avoid wasting their efforts, money and time in ineffective programs or practices. We suggest that courses like the one proposed here, which combine introductory content on neuroscience and refutation texts about specific neuromyths could be included in both initial teacher training and ongoing professional development programs for educators. Ideally, the targeted

neuromyths should include those that are more prevalent in each region, and it would be convenient to supplement their refutations with introductory content about neuroscience. These formative actions could help empower teachers to become more critical about brain-based claims and thoughtful consumers of neuroscientific evidence. However, it would be advisable that educational authorities collaborate with neuroscience experts to guarantee that neuroscience training programs and courses for school teachers are based on sound scientific evidence and not on misunderstandings or oversimplifications of research.

Footnotes

Although Ferrero et al. [23] decided to discard the true statement in item 14 ("learning is not due to the addition of new cells to the brain") from their analysis given that there was some scientific evidence against it [69], in this study we chose to analyze it anyway. That was possible because Ferrero et al. kindly provided us with the raw data from their study. Thanks to this data, we also compared the prevalence of the neuromyth in item 2 of our study ("children must acquire their native language before a second language is learned. If they do not do so neither language will be fully acquired") to the results obtained from their sample of bilingual regions of Spain. As previously noted in other studies [23,24], we noted that 3 out of 15 neuromyths in the original survey were actually true statements about the brain. We then included them in the general knowledge questionnaire. Ferrero et al. [23] provided us with their raw data to analyze the prevalence of the neuromyth related to bilingualism in their sample and to compare it to our sample.

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Conflict of Interest Statement

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

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