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The reported effects of neuroscience literacy and belief in neuromyths among parents of adolescents

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Abstract

Neuroscience research has increased our understanding of brain development, but little is known about how parents of adolescents engage with this neuroscientific information. Dutch parents completed a digital survey on neuromyths, neuroscience literacy and views of the adolescent brain and behaviour. These parents believed 44.7% of neuromyths and showed reasonable neuroscience literacy (79.8%). Stronger neuromyth belief predicted a more negative view on adolescent brain development. About 68% of the parents reported that they had changed their parenting behaviour based on their understanding of neuroscientific findings. These self-reported changes most often reflected changes to parents' own behaviour. The results of this study underline the importance for scientists and parents to engage in scientific activities to promote respectful and trusting relationships between them. These relationships have the potential to make communication about adolescent brain development between scientists and parents more effective and will empower parents to use correct information as a basis for their decisions around raising their adolescents.

Keywords

Popularization of science and technology; Public perception of science and technology; Public understanding of science and technology

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Context

Neuroscientific research has contributed enormously to current understanding and knowledge around the complex processes in the developing brain [Blakemore & Choudhury, 2006; Buckley, Broadley & Cascio, 2018; Casey, Tottenham, Liston & Durston, 2005; Giedd et al., 1999; Giedd, 2004; Goddings, Beltz, Peper, Crone & Braams, 2019; Qu, Pomerantz, McCormick & Telzer, 2018; Sowell, Trauner, Gamst & Jernigan, 2007; Tamnes et al., 2017]. This work has been vital in demonstrating that adolescence is a period of continued brain development, which underlines the frequently observed behavioural changes, such as increases in risk taking behaviour and self-awareness [Blakemore, 2012; Dahl, 2004]. Neuroscientific information about adolescent brain development and subsequent behaviour can be very appealing to a specific subgroup of the general public, — parents of adolescents —, who want to understand and support their children during adolescence, a period parents often experience as challenging [O'Connor, Rees & Joffe, 2012; van de Werff, 2017]. Furthermore, parental influence on adolescents' behaviour remains extensive during adolescence, as the role parents play changes from a leading role in childhood towards a more managing and structuring role of behaviour during adolescence [Dishion & McMahon, 1998; Kincaid, Jones, Sterrett & McKee, 2012]. While multiple lines of research have focussed on the way in which insights about the brain have influenced everyday practice, such as learning or the understanding of social interaction [O'Connor et al., 2012], little is known about how neuroscientific understanding of the developing adolescent may affect the beliefs and behaviours of an important stakeholder group: parents of adolescents.

But how are insights about the brain communicated to parents of adolescents? Popular approaches for communicating scientific findings are informed by the information deficit model. In this model, information flows from experts to the general public in order to change individuals' beliefs and behaviours. The aim of the information deficit model is to bridge the knowledge gap between scientists and the general public. It is a one-way communication model that assumes that scientific facts speak for themselves and that it would be enough for scientists to provide the general public, which includes parents of adolescents, with the correct information [Metcalfe, 2022; Miller, 1983]. However, it is yet unknown how neuroscientific findings, transmitted via this information deficit model, might affect parents' beliefs and behaviours towards their adolescents. In the current study, we therefore investigated two different aspects of neuroscience communication. We firstly explored how neuroscientific information is understood by parents. Secondly, we investigated how parents of adolescents act upon this neuroscientific information.

It is not straightforward for those without a scientific background to interpret the findings from primary sources such as scientific papers. As a result, for most parents, (online) media, magazines and popular scientific books about the teenage brain and parenting adolescents are their main sources of neuroscientific information [Herculano-Houzel, 2002; Racine, Waldman, Rosenberg & Illes, 2010]. The influence of science communication through mainstream media on society has been reported before [Allen, 2020; O'Connor et al., 2012; Walter, Brooks, Saucier & Suresh, 2020], and media coverage of adolescent brain development is often negatively framed, using words such as irrational and impulsive to address adolescent behaviour [van de Werff, 2017]. Whereas many studies speak about the dangers of risk-taking behaviours in adolescents, only a few investigations discuss these same behaviours, but refer to it as more explorative behaviour in which risk-taking sometimes might be necessary to adapt to the environment and therefore learn [Duell & Steinberg, 2018]. Moreover, other investigations on public engagement with science illustrated that individuals interpret science in ways that cohere with their pre-existing values and beliefs [Joffe & Haarhoff, 2002; Kahan, Jenkins-Smith & Braman, 2011; Morton, Rabinovich, Marshall & Bretschneider, 2011]. A predominantly negative framing of adolescent brain development may have undesirable consequences, as it could reinforce certain adverse normative views of adolescent behaviour [Choudhury, McKinney & Merten, 2012]. This may lead to negative parental expectations of adolescent behaviour, which in turn may negatively influence the actual behaviour of their children [Buchanan & Hughes, 2009].

In addition to possible consequences of negative framing of adolescent brain development, the lack of nuance in media reporting can influence the effects of perceived information on neuroscientific findings [Illes et al., 2009; N. M. van Atteveldt, van Aalderen-Smeets, Jacobi & Ruigrok, 2014] and could possibly lead to misconceptions. These misconceptions occur in many different settings, from teaching to health care, and are known as neuromyths. Neuromyths are defined as "misunderstandings, misreadings or misquotations of neuroscientific facts to make a case for use of brain research in education and other contexts" ["Understanding the Brain", 1970]. Important for the definition of a neuromyth is that there has to be some remaining trace of scientific origin from which the myth sprung. For example, one of the most influential neuromyths is that people with a dominant left hemisphere are mostly analytical, while people with a dominant right hemisphere are mostly creative. Many find this idea intuitive, and images in popular and accessible articles showing 'hot spots' in the brain for specific functions and tasks may promote the idea that the brain consists of isolated, functional units [Howard-Jones, 2014]. However, neuroimaging studies have shown that virtually all cognitive tasks require complex neural networks which are distributed across both sides of the brain [Casey et al., 2005].

Most studies on the prevalence of neuromyths have been conducted among teachers and a few have focussed on the general public. The results show that both groups have a high belief in neuromyths [Dekker, Lee, Howard-Jones & Jolles, 2012; Ferrero, Garaizar & Vadillo, 2016; Herculano-Houzel, 2002; Howard-Jones, Franey, Mashmoushi & Liao, 2009; Macdonald, Germine, Anderson, Christodoulou & McGrath, 2017; Tardif, Doudin & Meylan, 2015]. Parents form a specific group of interest as several neuromyths relate to how parents ought to behave in relation to their child [Leysen, 2021] and because it is known that parents' beliefs and expectations, influence the actual behaviour of their adolescent children [Hines & Paulson, 2006; Jacobs, Chhin & Shaver, 2005]. Therefore, our first aim on how scientific information is understood, will be to explore the belief in neuromyths among parents.

The development of neuromyths has been related to the large interest in neuroscientific information [Beck, 2010]. Neuroscientific information mainly reaches the general public via (online) media such as popular science websites or magazines, newspapers and television programmes. Reading popular science magazines and newspapers has previously been related to an increase in general brain knowledge [Herculano-Houzel, 2002], also called neuroscience literacy. Investigations of neuroscience literacy have shown contradicting results. Research by Dekker et al. [2012] on teachers from the Netherlands and the United Kingdom showed that neuroscience literacy does not protect teachers from believing in neuromyths, while other studies, showed that neuroscience literacy increases the ability to identify neuromyths [Howard-Jones et al., 2009; Macdonald et al., 2017]. Since neuroscience literacy seems to have an effect on how neuroscientific information is understood by parents, it is important to assess both aspects in parents.

To gain insights into the impact of neuromyths and neuroscience literacy on parents, we investigated the relationship between these two factors and parents' views on adolescent brain development and their parenting behaviours. A recent study showed that the concept of the 'teenage brain' was predominantly associated with negative adolescent behaviours among parents [Altikulaç et al., 2019]. Additionally, we investigated how information is understood by parents. We will study how the aforementioned associations with the concept 'teenage brain' are formed and what consequences they might have on the beliefs and behaviours of parents, as it would be of great concern if parents would base their views and behaviours on incorrect beliefs about the brain.

Next, we will focus on how parents act upon this information and the more specific question we address is how neuroscience knowledge could influence the way in which parents cultivate the managing role when parenting their adolescents. According to van de Werff [2017] neuroscience knowledge may influence parents to act as an "external frontal lobe", meaning that they play a role in regulating adolescents' behaviour. This term originates in the wealth of research showing that the prefrontal cortex, a region of the brain that continues to develop during adolescence, plays a crucial role in self-regulation of behaviour [Banfield, Wyland, Macrae, Münte & Heatherton, 2004; Mayeli et al., 2019; Werchan & Amso, 2017]. By functioning as an 'external frontal lobe' parents compensate for the self-regulatory skills their adolescents are still developing.

Objective

The current study firstly focusses on the understanding of neuroscientific information (Research Question 1a). We assessed neuroscience literacy and the prevalence of general neuromyths among parents of adolescents. We also investigated predictors of these beliefs and knowledge, namely the effects of factors that have previously been shown to play a role in the prevalence of neuromyths [Dekker et al., 2012]. These include level of education, reading popular neuroscientific books, reading newspapers and reading neuroscientific articles, such as popular neuroscientific articles on websites about education and parenting. Next, we gained insight into the potential consequences of parents' neuromyth belief and neuroscience literacy. To address this, we investigated parents' views on adolescent brain development and how these views are related to neuromyth belief and literacy (Research Question 1b). To go beyond the understanding of neuroscientific information, we examined the communication from parents to their children asking them whether and how they think they have changed their parenting behaviours based on neuroscientific information (Research Question 2).

We hypothesize that the belief in neuromyths and neuroscience literacy among parents will be comparable to scores found among the general public in previous investigations [Macdonald et al., 2017]. We further expect that actively seeking neuroscientific information (e.g. through reading articles and (neuro)scientific books) will increase parents' score on neuroscience literacy, but will not protect against belief in neuromyths, in line with pervious work in a Dutch sample [Dekker et al., 2012]. Media reporting may, due to oversimplification and misquotation, influence the development of neuromyths [Illes et al., 2009; N. M. van Atteveldt et al., 2014]. At the same time the media has a tendency to frame discussion of adolescent brain development negatively [van de Werff, 2017]. Parents receive information from the media and come across both neuromyths and negatively framed information, therefore we hypothesize that belief in neuromyths is related to negative views on adolescent brain development. Further, parents with a high score on neuroscience literacy may have a better understanding of adolescent brain development and may therefore be protected against the negatively framed information in the media. Finally, when parents actively seek for neuroscientific information in different (online) media to help and guide their adolescents, they come across both neuroscientific evidence and neuromyths and might be unable to distinguish between the two. We therefore hypothesize that parenting behaviour will be influenced by neuroscientific information and that this is related to both their (unconscious) neuromyth belief and their neuroscience literacy.

Materials & Methods

3.1 Participants

The researchers contacted schools interested in participating in scientific research to ask for permission to send recruitment information to parents. Schools that agreed to participate were asked to forward an email with information about the research project to all parents with at least one child between 12 and 18 years old. The total sample included 193 parents from different regions in the Netherlands as collected and described by Altikulaç et al. [2019]. Whereas Altikulaç et al. [2019] analysed both adolescents' and parents' associations around the word 'teenage brain', this study focuses on belief in neuromyths, neuroscience literacy, views on adolescent brain development and subsequent parenting behaviours in Dutch parents of adolescents. Data of 40 parents were excluded because they did not finish the questionnaire. A total of 153 parents were included in the analysis (80.8% female). The average age of the participants was 47.2 years (SD = 4.20) and they had an average of 2.4 children. The average age of the children was 14.1 years (SD = 3.64) with an age range between 2 and 28 years (see descriptive statistics, Table 1).

3.2 Procedure

The full research project included multiple questionnaires and was presented as a study of parents' knowledge and views about the adolescent brain and their views on the relationship between adolescent brain development and adolescent behaviour. The information sent to schools and parents did not contain the term 'neuromyth'. Parents who were interested and chose to participate, followed a link to an online survey available via the Qualtrics website. Prior to completing the questionnaire participants were asked to provide informed consent. A winner of a book was drawn at random from all parents who participated in this study and chose to provide us with their contact details after they finished the questionnaire.

All procedures were approved by the ethics committee of Vrije Universiteit Amsterdam, Faculty of Behavioural and Human Movement Sciences. The questionnaire started with questions about age, gender, level of education and family composition (number of children and age), followed by statements to measure belief in neuromyths and neuroscience literacy, views on adolescent brain development and finally questions about parenting behaviours. Average completion time was 34 minutes.

Table 1. Descriptive statistics of the participants: age, gender, level of education and number of children.

Parents of adolescents	
Gender (N = 153)	80.4% female; 19.0% male; .6% unknown
Age (N = 150)	
Mean (SD)47.2	(4.20)
Range	35 – 59
Education (N = 153)	
Primary school	.7%
Secondary school	7.8%
MBO*	15.7%
HBO*	41.8%
WO*	33.3%
Other	.7%
Number of children in the family	
Mean (SD)	2.4 (.83)
Range	1–5
Average age (SD; range)	14.1 years (3.64; 2 – 28 years)

**The Dutch schooling system after secondary school is divided into MBO (middelbaar beroepsonderwijs), which is focussed on vocational training, HBO which focussed on general higher education and WO (wetenschappelijk onderwijs, i.e., university). HBO education focuses on vocational training in subjects such as nursing and teaching, whereas WO education offers higher level programs at research universities, such as medicine and law.*

3.3 *Measures and statistical analysis*

The data was analysed using Statistical Package for the Social Sciences (SPSS) version 26.0 for Windows. For all analyses, a statistical threshold of $\alpha = .05$ was used. Below, we will describe the measures and how the generated data were analysed per measure.

3.3.1 Parents' understanding of neuroscientific information

1a. Belief in neuromyths and neuroscience literacy. A questionnaire consisting of 20 items was used to measure belief in neuromyths (eight items) and neuroscience literacy (twelve items). Participants read statements and were asked to indicate if these were 'true' or 'false'. The neuromyth statements and general brain statements were presented in random order and can be found in appendix A. Belief in neuromyths was measured using an adapted version of Dekker et al. [2012]. Seven neuromyths were based on the comprehensive work of the "Understanding the Brain" [1970], for example 'we only use 10% of our brains'. We added one neuromyth related to the interpretation of neuroscientific techniques: 'Neuroimaging techniques can be used to diagnose autism or ADHD'. Since the general public lacks knowledge on how brain images are generated, there is a risk that they consider an image of the brain proof of a certain mental state [Pasquinelli, 2012]. Neuroscience literacy (general brain knowledge) was measured with twelve items containing general statements about the brain, adapted from Dekker et al. [2012] based on sample study of Herculano-Houzel [2002]. For both neuromyth questions as well as neuroscience literacy, content validity was assessed by asking expert neuroscientists to evaluate the survey. An example of a general statement from the survey is 'Formation of new connections in the brain can continue into old age'. True (N=10) and false (N=10) statements were balanced across the questionnaire. As all the eight neuromyths statements were false (as neuromyths are false interpretations), two neuroscience literacy questions were also formulated to be false. The other ten neuroscience literacy statements were true. Belief in neuromyths was determined by the total percentage of incorrect answers on the eight neuromyth statements (i.e., choosing 'correct' on the neuromyth statements). Neuroscience literacy was determined by the percentage of correctly answered knowledge questions (i.e., choosing 'correct' on the general brain knowledge questions).

1b. Predictors of belief in neuromyths and neuroscience literacy. In the second part of the survey parents indicated whether and how often they read various Dutch newspapers and sources that contain neuroscientific information, such as popular scientific magazines and online scientific blogs. Responses to all questions were given on a scale from 0 to 3: less than once a month (0), monthly (1), weekly (2), and daily (3).

An alternative scale was used for questions regarding reading of popular science books. Participants indicated whether or not they read popular scientific books and if so which books they read.

The variable 'reading newspapers' was determined by the sum score (between 0 and 3) of how often the ten various national newspapers were read (between 0 and 3 for each newspaper; maximum score of 30). The variable 'reading neuroscientific articles' was based on the sum of three different categories. First, the score on the question 'how often do you read popular scientific magazines?' Second, the highest score on two questions regarding reading educational/pedagogical articles ('how often do you read magazines on education and / or pedagogy?' and 'how often do you read professional magazines on education and / or pedagogy?'). Third, the highest score on three questions regarding reading scientific articles about education, development and parenting ('how often do you read informational websites / blogs on education and / or pedagogy?', 'how often do you read informational websites / blogs on scientific research?' and 'how often do you read scientific journals on education, development and / or pedagogy?'). The maximum score on 'reading neuroscientific articles' was 9 (the highest maximum score was 3 on each of the three different categories). The variable 'reading neuroscientific books' was determined by whether or not popular neuroscientific books were read (yes or no question). To examine which factors predict the parents' neuromyths score, a multiple regression analysis was performed with the percentage of believed neuromyths as the dependent variable, and with educational level, neuroscience literacy, reading newspapers, reading neuroscientific articles and popular neuroscientific books as predictors. To examine the factors that predict neuroscience literacy, a multiple regression analysis was performed with percentage score on neuroscience literacy (dependent variable) and the following predictors: educational level, reading newspapers, reading neuroscientific articles and reading popular neuroscientific books.

1c. Effects of belief in neuromyths and neuroscience literacy on views of adolescent brain development. Positive and negative views on adolescent brain development were measured with nine statements in which adolescent behaviour was related to adolescent brain development (as used in Altikulaç et al. [2019]; see appendix B). These nine items included multiple adolescent stereotypes, such as being emotionally driven, and struggling to plan activities. Four of these items were positively framed, for example 'Adolescents' brains are more flexible than those of adults. As a result, adolescents are more able to learn from their mistakes and adjust their behaviour'. Five other statements were negatively framed, for example 'Due to hormonal changes, adolescents often have intense emotions, which they find difficult to properly control'. Answers were scored on a Likert-scale from 1 to 5 in which 1 meant 'totally disagree' and 5 'totally agree'. The nine statements can be found in appendix B.

A mean agreement score was calculated separately for the five negative statements and four positive statements. A paired sample t-test was carried out to examine differences in endorsement of positive versus negative adolescent brain statements. Next, two multiple regression analysis were carried out with mean agreement scores on positive statements and mean agreement scores on negative statements as dependent variables. Predictors were belief in neuromyths (%) and neuroscience literacy (%).

3.3.2 Impact of neuroscientific communication

2. Consequences of belief in neuromyths and neuroscience literacy on parenting behaviours. Parents were asked whether or not (binary scale) they had ever adapted their parenting behaviours based on insights from (scientific) research on brain development or the (adolescent) brain. If they answered 'yes' to this question, an open-ended follow-up question then asked them to describe how these insights led to changes in their behaviour.

As a first step, we used a binomial test to analyse whether parents changed their parenting behaviours based on neuroscientific information more often than would be predicted at chance level. In addition, we conducted an exploratory analysis to examine whether experienced parents (parents who had already raised an adolescent) differed from parents who were currently parenting their first adolescent. To examine whether belief in neuromyths and neuroscience literacy predicted parental adaptations in parenting behaviours, a logistic regression analysis was performed. Adaptation of parenting behaviours (yes/no) was the dependent variable. Predictors were belief in neuromyths (%) and neuroscience literacy (%).

Secondly, we qualitatively analysed the open-ended question about how parents changed their parenting behaviour by using a coding scheme based on the two moral repertoires suggested by van de Werff [2017]. van de Werff [2017] theoretically distinguishes two types of parental behaviour, called 'moral repertoires', which describe ways in which parents can act as "an external frontal lobe". The first moral repertoire focusses on protecting the adolescent against external stimuli. This includes disciplining the adolescent by providing clear boundaries and strict rules. The second moral repertoire is more focussed on guiding the natural development of the teenage brain. This repertoire describes the role of parents more as motivating coaches, who stimulate, support and steer the adolescent, e.g. helping them to plan their activities, such as homework [van de Werff, 2017]. Two additional categories were added based on a first exploration of the data. A more detailed description of the coding categories can be found below:

(1) *Protection of adolescents from external stimuli (based on moral repertoire 1 [van de Werff, 2017])*: this parenting behaviour refers to disciplining the adolescent, providing clear boundaries and strict rules.

(2) *Motivating the adolescent (based on moral repertoire 2 [van de Werff, 2017])*: this parenting behaviour encourages, supports and guides the adolescent in their behaviour.

(3) *Focusing on parents' own behaviour*: this category focuses on how the parent has changed his / her own behaviour, e.g. 'I show them that I understand their emotions'.

(4) *Other*: examples that did not fit categories 1 to 3.

The four codes were not seen or used by the participants themselves; they were only used to label the answers of parents during coding of the data. All data were independently coded by two raters using the four categories described in the coding scheme. Before proceeding with the analysis of the data based on these codes, these two raters met to discuss any discrepant codes until consensus was reached for each response and the coding categories were adjusted accordingly. To measure consistency of the ratings within the different scoring categories, O'Connor and Joffe [2020] suggested that at least 10–25% of the data units should be re-coded by another independent rater. In our investigation, a third rater scored 30 out of 90 (33%) randomly selected answers of parents. This third rater received the final coding scheme as described above with the description of categories 1–4, including an example of parenting behaviour that would fit in each category. The Cohen's Kappa was calculated for these 30 answers compared to the consensus scores of the first two raters and was 0.86, therefore the inter-rater reliability was found to be sufficient [Landis & Koch, 1977; McHugh, 2012].

A non-parametric chi-square analysis was carried out to examine differences in the prevalence of the four different parenting behaviours.

Results

4.1 Parents' understanding of neuroscientific information

1a and 1b. Prevalence and predictors of belief in neuromyths and neuroscience literacy. The proportion of correct and incorrect answers on each neuromyth is summarized in Table 2. Overall, parents of adolescents believed on average 44.7% of the neuromyths. Four out of eight neuromyths were believed by more than 50% of the parents. The most prevalent neuromyths were (1) 'Children are less attentive after consuming sugary drinks and /or snacks' and (2) 'People with a dominant left hemisphere are mostly analytical, while people with a dominant right hemisphere are mostly creative'. These neuromyths were believed by respectively 77.8% and 71.2% of the parents (see Table 2). In contrast, the neuromyths 'The bigger your brain, the smarter you are' and 'Learning problems, such as dyslexia, cannot be improved by interventions or training' were both correctly answered by 91.5% of the parents. A regression analysis revealed that the model containing all predictors (i.e. educational level, neuroscience literacy, reading newspapers, reading neuroscientific articles, reading books) was not statistically significant ($F(5, 110) = 1.286$, $p = .28$) indicating that this model was unable to predict the average percentage of belief in neuromyths.

The average percentage of correct answers on the general knowledge questions (neuroscience literacy) was 79.8% (see Table 2). The question 'boys have bigger brains than girls' was most often answered incorrectly namely by 85.0% of the parents. The question most often answered correctly was 'Vigorous exercise can improve mental function' by 98.0% of the parents. A regression analysis was carried out to predict neuroscience literacy based on level of education and reading newspapers, neuroscientific articles and books. A significant regression equation was found ($F(4, 116) = 5.709$, $p < .001$) with an R^2 of 0.164, indicating that neuroscience literacy was significantly predicted by both educational level ($\beta = 0.267$, p = .003) and reading neuroscientific articles ($\beta = 0.175$, p = .045) (see Table 3A). The higher the level of education and the more neuroscientific articles parents had read, the more general brain knowledge they had.

1c. Effects of belief in neuromyths and neuroscience literacy on views of adolescent brain development. A paired sample t-test showed a significant difference in the extent to which parents agreed with the positive adolescent brain statements, ($M = 3.17$, $SD = .54$) and the extent to which parents agreed with the negative adolescent brain statements, ($M = 3.39$, $SD = .50$): $t(146) = (3.987)$, $p < .001$. This seems to indicate that generally parents endorse a more negative than positive view of adolescent brain development.

A linear regression analysis showed that neither neuromyths nor neuroscience literacy predicted parents' endorsement of positive adolescent brain statements ($F(2,138) = 1.220$, $p = .298$). However, a second linear regression analysis showed that belief in neuromyths, but not neuroscience literacy predicted the endorsement of negative adolescent brain statements ($F(2, 138) = 10.118$, $p < .001$) with an R^2 of 0.358; see Table 3B and 3C). This indicates that parents who believed more in neuromyths also had a more negative view of adolescent brain development.

4.2 *Impact of neuroscientific communication*

2. Consequences of beliefs in neuromyths and neuroscience literacy on parenting behaviours. A total of 99 (64.7%) parents indicated that they had (at some point) changed their parenting behaviour based on their understanding of neuroscientific information (see Figure 1A). Binomial tests indicated that the proportion of parents who changed their parenting behaviours was 0.65 which is significantly higher than the expected proportion of 0.50 based on chance level, $p < .001$).

Among parents raising their first adolescent child, the proportion who changed and who did not change their parenting behaviours did not significantly differ from chance level. Among parents who had already raised an adolescent, a

Table 2. Correctness of responses (N = 152) for each neuromyth assertion. Note that 'incorrect answer' on the neuromyth statement means that the participant answered the neuromyth to be correct and vice versa. For neuroscience literacy (T) means that the statement is true, (F) means that the statement is (F)The neuromyth statements and general brain statements were presented in random order and can be found in appendix A. *Note.* In order to balance the number of true/false answers, the correct answer for all eight neuromyths and two neuroscience literacy questions were false, while the other ten neuroscience literacy questions were true.

Neuromyths	Incorrect answer (%)	Correct answer given (%)	Unanswered (%)	Neuroscience literacy	Incorrect answer (%)	Correct answer given (%)	Unanswered (%)
Children are less attentive after consuming sugary drinks and / or snacks	77.8	20.3	1.9	Boys have bigger brains than girls (T)	85.0	14.4	.6
People with a dominant left hemisphere are mostly analytical. while people with a dominant right hemisphere are mostly creative.	71.2	28.1	.7	The left and right hemispheres of the brain always work together (T)	50.3	49.0	.7
It has been scientifically proven that fatty acid supplements (omega-3 and omega-6) have a positive effect on academic achievement	66.7	31.4	1.9	Memories are stored in the brain in a network of cells distributed throughout the brain (T)	26.1	73.2	.7
We only use 10% of our brain	51.0	48.4	.6	The brain can change because of environmental influences. for example by what is learnt at school (T)	16.3	83.0	.7
Brains of boys and girls are different: therefore boys have more talent for mathematics and science. while girls have more talent for languages	42.5	56.9	.6	Circadian rhythms shift during adolescence causing students to be tired during the first lessons at school (T)	13.1	86.3	.6
Neuroimaging techniques can be used to diagnose autism or ADHD	34.6	64.7	.7	Production of new connections in the brain can continue into old age (T)	12.4	86.9	.7
Learning problems. such as dyslexia. cannot be improved by interventions or training	7.8	91.5	.7	Hormones have an influence on how brains develop (T)	12.4	86.9	.7
The bigger your brain. the smarter you are	6.5	91.5	2.0	We use our brains 24 hours a day (T)	5.9	93.5	.6
Mean score	**44.7**	**54.0**	**1.3**	The brains of boys and girls develop at the same rate (F)	5.9	94.1	
				Brain development has finished by the time children reach secondary school (F)	3.3	96.1	.6
				Extended rehearsal modifies the brains' neural connections (T)	2.6	96.7	.7
				Vigorous exercise can improve mental function (T)	0.7	98.0	1.3
				Mean score	**19.5**	**79.8**	**.7**

Table 3. Predictors of neuroscience literacy (A), predictors of agreeing with positive brain statements (B) and agreeing with negative brain statements (C). *Statistically significant; **Confidence Interval.

A.

Effect	B	SEB	β	t	p	95% CI**	
						LL	UL
(Intercept)	66.595	4.427		15.042	< .001	57.826	75.364
Educational level	3.071	1.027	.267	2.989	.003*	1.036	5.106
Reading newspapers	−.486	.401	−.103	−1.212	.228	−1.281	.308
Reading neuroscientific articles	1.098	.542	.175	2.024	.045*	.024	2.172
Reading books	3.007	1.930	.141	1.558	.122	−.815	6.830

B.

Effect	B	SEB	β	t	p
(Intercept)	1.856	.397		4.678	< .001
Belief in neuromyths	.004	.003	.128	1.521	.131
Neuroscience literacy	.002	.005	.029	0.344	.731

C.

Effect	B	SEB	β	t	p
(Intercept)	1.391	.347		4.005	< .001
Belief in neuromyths	.009	.002	.329	4.133	< .001*
Neuroscience literacy	.007	.004	.138	1.737	.085

binomial test showed that the proportion of parents who changed their parenting behaviour (0.75) was significantly higher than the expected proportion at chance level (0.50), $p < .001$ (see Figure 1B and 1C).

A logistic regression analysis showed that neither belief in neuromyths nor neuroscience literacy predicted the change in parenting behaviours ($\chi^2(2)$=3,840, $p < 0.147$). Parents with a high score on belief in neuromyths (Exp(b) = 1.017, SE = .011, $p = .117$) or neuroscience literacy (Exp(b) = .978, SE = .019, $p = .237$) did not change their parenting behaviour more so than parents with a low score on belief in neuromyths or neuroscience literacy.

In this study, we asked parents whether they base their self-reported behavioural changes on their knowledge about neuroscientific findings. The majority of the parents indicated that they did (around 68%). On the open-ended question, a total of 90 parents reported strategies of parenting behaviour that fitted into the four described categories, and 9 parents indicated that they had changed their behaviour, but did not give specific examples. In Figure 2, the distribution of the answers over the different coding categories is shown. To examine differences in occurrence of the different parenting behaviours, a non-parametric chi-square analysis was conducted. This analysis showed that parents significantly more often mentioned behaviours that fitted into the third category with a strong focus on (changing) their own behaviour ($\chi^2(3, N{=}90) = 35.422$, $p < .001$) (see Figure 2).

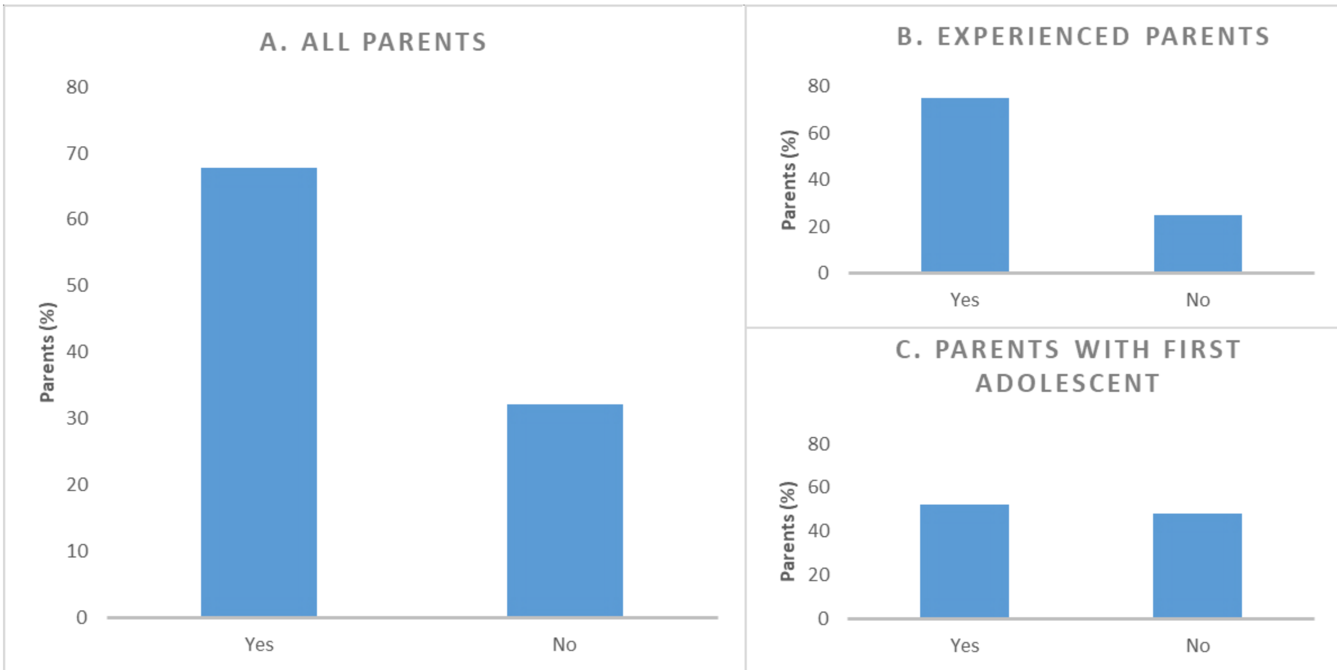

Figure 1. Parents' responses to whether or not they changed their parenting behaviours. *Note.* Parents responses (Yes or No, in %) to the question 'did you ever change your parenting behaviours based on insights from (scientific) research on brain development or the (adolescent) brain. (A) All parents (N=153), (B) Parents who had previously parented an adolescent (n = 106), (C) Parents with their first child in adolescence (n = 47).

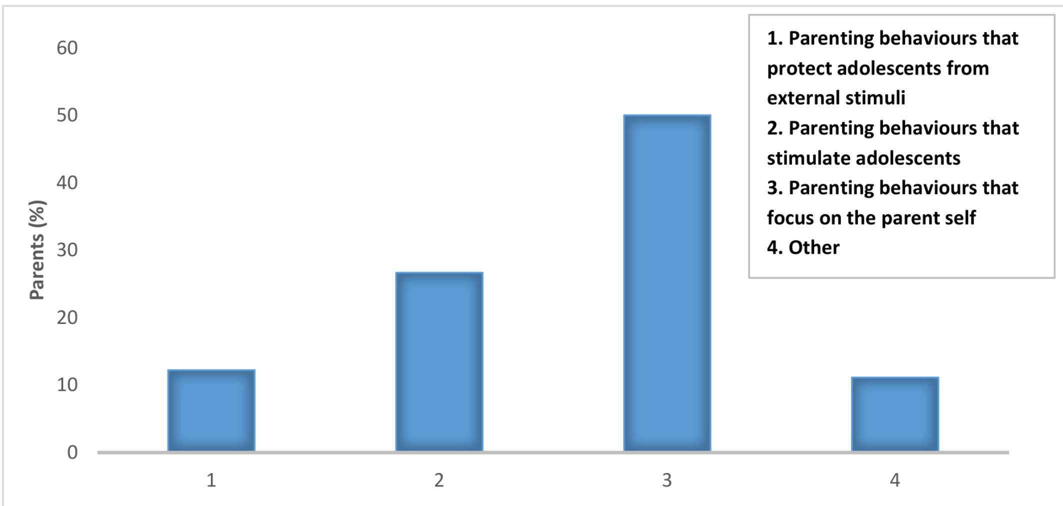

Figure 2. Self-reported changes in parenting behaviours. *Note.* The figure displays the distribution across the different categories of the self-reported changes in parenting behaviours. It only includes parents who answered the open-ended question about how they changed their parenting behaviours based on (scientific) research or (adolescent) brain development (N=90).

The 45 parents who gave answers belonging to this third category mentioned that they had a better understanding of their adolescent, that they were able to accept their behaviour and that they were more patient with them now. Examples in this category include 'I understand that their brain is still developing and adapt to their behaviours', 'I accept their mood swings' and 'I am more patient now'. Only 11 parents reported changes in their behaviours which aimed to protect adolescents from external stimuli (i.e. the first category). Examples from this first moral repertoire of van de Werff [2017], included 'I am strict' and 'I set clear boundaries'. A total of 24 parents brought up behaviours that fitted the second moral repertoire of van de Werff [2017], in which adolescents are to be encouraged and supported during adolescence. The most frequently mentioned parenting behaviour in this category was 'I help them to plan their homework', which was mentioned by 11 of 24 parents in this category.

Discussion

In this study we first explored how parents of adolescents understand neuroscientific information. We examined the prevalence of neuromyths among parents of adolescents, as well as their neuroscience literacy. Next, we asked parents how this neuroscientific information had influenced their parenting behaviour.

In line with our expectations, our results on how neuroscientific information is understood, indicated that parents believed a significant number of neuromyths (on average half of the neuromyths). Despite this belief in neuromyths, they also showed high levels of neuroscience literacy (around 80%), in particularly when compared with previous investigations on teachers by Dekker et al. [2012] and Idrissi, Alami, Lamkaddem and Souirti [2020] in which teachers scored respectively 73% and 65% on neuroscience literacy and when compared with an investigation on the general public [Herculano-Houzel, 2002] in which the general public had a score of around 50%. Furthermore, our results indicated that the higher the level of parents' education and the more neuroscientific articles they read, the more general brain knowledge parents had. We also examined how both neuromyths and neuroscience literacy specifically affected parents' views of their adolescent children. Parents appear to hold a relatively negative view of the effects of adolescent brain development: they agreed more strongly with negatively framed information on adolescent brain development, compared with positively framed information. Interestingly, parents with a high score on belief in neuromyths also held more negative views on adolescent brain development. With respect to how this information is communicated to their adolescents, this is an important conclusion as about 68% of the parents reported that they had (at some point) changed their parenting behaviour based on their understanding of neuroscientific findings. This was particularly the case among parents who already had raised another adolescent. The reported changes most often focussed on changes in parents' own behaviour (e.g. becoming more accepting, more patient). These findings and their further implications will be discussed in more detail below.

5.1 Parents' understanding of neuroscientific information

The results of our study indicated that parents believed around half of the neuromyths and were able to answer 80% of the general brain knowledge questions correctly. This is in line with previous research in which the general public had a high score on general brain knowledge and at the same time believed in a considerable number of neuromyths [Dekker et al., 2012; Ferrero et al., 2016; Macdonald et al., 2017]. It seems that parents who have an interest in the brain and its development are exposed to both correct and incorrect information, and are sometimes unable to distinguish between the two.

Our results differ from previous investigations among teachers, which showed that increased knowledge about the brain also predicts an increased belief in neuromyths [Dekker et al., 2012; Ferrero et al., 2016]. Our investigation also showed that both educational level and reading neuroscientific articles are positively related to neuroscience literacy. Lastly, our investigation did not demonstrate that reading neuroscientific articles and books are predictors of a reduced belief in neuromyths which is contradictory to the research of Ferrero et al. [2016] and Macdonald et al. [2017]. On one hand, the high score on neuorscience literacy of parents indicates the growing interest and curiosity around the developing brain. On the other hand, the high score on the neuromyth statements is concerning, in particular since many of these statements address understanding of development and learning. As a result, misconceptions among parents could be harmful for the developing adolescent.

These results provide important insights into ways scientific knowledge can be best communicated to parents. The information deficit model of scientific communication is based on the assumption that one-way communication of scientific knowledge to the general public should be sufficient to increase understanding of science by the general public [Metcalfe, 2022; Simis, Madden, Cacciatore & Yeo, 2016]. Previous investigations showed that the information deficit model plays an important role in science communication [Metcalfe, 2022; Sturgis & Allum, 2004]. However, research on complex issues, such as climate change [McDivitt, 2016; Suldovsky, 2017] and health care [Ko, 2016], showed that the information deficit model might be too simplistic and inaccurate when characterizing relationships between (complex) knowledge, beliefs and behaviours [Suldovsky, 2017]. Communication about neuroscience is challenging as well and therefore simply providing parents with complex information about neuroscientific research, in line with the information deficit model, may not be the most adequate approach to ensure effective communication [Howard-Jones, 2014; O'Connor & Joffe, 2013], as it is difficult to make neuroscientific findings applicable and neuroscientific concepts may easily be misunderstood [O'Connor & Joffe, 2013]. Therefore, the field of neuroscientific research may require neuroscience communication specialists, as suggested by Dekker et al. [2012]. A recent investigation by Snoek and Horstkötter [2021] shows that there is still a gap between (neuro)science and its applicability to parenting practices. When translating (neuro)scientific findings to practical advice, they suggest that not only policy makers and media, but also parents themselves should critically examine the findings and should be encouraged to examine their own, often implicit ideas about neuroscientific findings. Our results are in line with these investigations and show that communicating neuroscientific information is more complex than the information deficit model allows for [Simis et al., 2016; Suldovsky, 2017]. In order to effectively engage parents with neuroscientific information, an important next step therefore could be to consider a dialogue model, which would encourage two-way interaction and would enable scientists and parents to recognise and make use of relevant neuroscientific information [Reincke, Bredenoord & van Mil, 2020; Metcalfe, 2022]. Participatory approaches to science communication, where scientists and parents collectively learn and jointly solve neuroscientific problems [Metcalfe, 2019], could help scientists to focus on neuroscientific research that is relevant for parents and help parents engage more actively in current neuroscientific research.

Activities that would fit the dialogue model of science communication include activities where parents directly engage with scientists [Altay & Lakhlifi, 2020; Das & Porcello, 2019], such as shared working groups comprising neuroscientists and parents. An example of such a format was used by Thompson and Nelson [2001], who initiated working groups between scientists and journalists, which were shown to contribute to greater mutual respect and understanding. Other practices include holding focus groups interviews with important stakeholders very early in the decision making processes when designing new (neuroscientific) studies [N. van Atteveldt, Tijsma, Janssen & Kupper, 2019]. The implementation of these practices may promote more respectful and trusting relationships between scientists and those making use of scientific findings, as indicated by Metcalfe [2022]. In their invesitgation, aimed at developing relationships between farmers and scientists through different activities in the context of a climate change programme, researchers showed positive effects on communication via both the information deficit model as well as via the dialogue model [Metcalfe, 2022]. It is important to acknowledge that the ultimate aim of these initiatives may not be to change the views or behaviours of parents, but to establish a respectful and trusting relationship between scientists and parents.

In the participatory model of science communication, there is a shift in power from scientists to the general public. In this model, the general public actively engages in neuroscientific research. Parents could have a direct influence on future neuroscientific research by proposing the research questions they would like answers to. For example, in the Netherlands, the government has launched the (Dutch) Research Agenda, which uses input from the general public to actively shape the direction of future research, thereby enabling them to contribute to both science and their own community. These initiatives based on both dialogic and participatory approaches hold potential for engaging parents as important stakeholders in neuroscientific research.

Our study showed that parents hold a more negative than positive view on adolescent brain development and its effects on adolescent behaviour. An analysis by Altikulaç et al. [2019] of the same sample of parents demonstrated that parents often associate the concept 'teenage brain' with undesirable behaviours such as 'being irresponsible' and less often with desirable behaviours such as 'being creative'. The results of this previous research also showed that these parents more often mentioned negative behaviours than adolescents themselves did. Our results on the negatively versus positively framed statement confirm this more negative than positive view of the adolescent brain among parents.

Previous investigations have shown that online media influence the perception of information about neuroscientific findings [Racine et al., 2010; N. M. van Atteveldt et al., 2014]. This lack of nuance and oversimplification, might play a role in the development of neuromyths. Simultaneously, media tend to have a strong focus on the negative aspects of adolescence and they often warn caregivers about difficult behaviours, such as an increase in risk-taking behaviour [Choudhury et al., 2012; van de Werff, 2017], while these same behaviours could as well be described as explorative behaviours necessary for quick adaptations and fast learning [Duell & Steinberg, 2018]. The general public mostly receives both neuromyths and this negative information from (online) media [Herculano-Houzel, 2002; Racine et al., 2010]. Our results suggest that parents' negative views are related to a greater belief in neuromyths. A high score on neuromyths might therefore be concerning since it relates to a more negative view on adolescent brain development. Previous research has shown that parents' expectations about adolescent behaviour predict subsequent adolescent behaviour. For example, if parents' expect certain risk-taking behaviours (i.e. being rebellious, impulsive) this may predict actual increases in these behaviours in adolescents [Buchanan & Hughes, 2009]. Our results show how important it is for scientists to communicate the results of their investigations in a nuanced and counterbalanced way, not only focussing on the negative aspects of adolescence, such as risk-taking and rebellious behaviour, but also on the more positive aspects such as the possibility of adolescents to quickly adapt to new environments [Crone & Dahl, 2012]. Illes et al. [2009] suggested that scientists should not only inform about neuroscientific findings, but should also facilitate the dialogue with the general public and present the complex results from (neuro)scientific research in an approachable form via different (online) media.

5.2 *Impact of neuroscientific communication*

The results of this study show that a large proportion of parents reported changing their parenting behaviours based on neuroscientific information. However, these changes were not predicted by either neuroscience literacy or neuromyth scores. This suggests that these changes were not specifically driven by the quantity or quality of the information parents had available to them, but perhaps by their interest in these topics. It highlights that parents find this information relevant to their parenting decisions. As we discussed in the introduction, parents who want to help and guide their adolescents might actively seek out neuroscientific information to inform their choices [O'Connor et al., 2012; van de Werff, 2017]. Although it is known that the information deficit model has its own important role in science communication [Metcalfe, 2022; Sturgis & Allum, 2004], from the above perspective an essential next step is to include dialogic approaches to science communication. In the dialogue model, careful communication between scientists and the general public about neuroscientific results is important, to ensure that parents are able to access relevant and meaningful information that is both scientifically correct and useful at a practical level. To move towards this model, we previously mentioned the implementation of shared working groups [Thompson & Nelson, 2001]. Furthermore, in order for scientists to learn about communication practices, in particular within the dialogue model of science communication, we think that it will be meaningful for them to be encouraged to take courses in science communication [Simis et al., 2016].

Additionally, we looked at how parents changed their self-reported parenting behaviours. The results showed that the way in which parents changed their parenting behaviour based on neuroscientific information was partially in line with the two moral repertoires distinguished by van de Werff [2017]. In the current sample, most parents did not focus on protecting their adolescent from external stimuli or being motivating coaches for their adolescents [van de Werff, 2017], but rather focussed on changing their own behaviour. This necessitated the addition of the third category in which parents take a step back and focus on themselves. Advice to parents of adolescents has previously focussed on putting things into perspective, to accept and even occasionally 'to bite their tongue', but also to be their manager, coach and mentor and therefore show high levels of caring and understanding [Jolles, 2016; van de Werff, 2017]. Our additional third category shows high levels of support and understanding, for example 'I have more patience now' and 'I understand the decisions that they make' and it also shows low levels of controlling behaviour, for example 'I try not to react when my child is unreasonable' and 'I accept that they often lie on the couch'. The results show that even though parents might have negative views on adolescent brain development, they still understand their children's behaviours and their negative views seem not to be reflected in their self-reported parenting behaviours. A better understanding of the adolescent brain may help parents to understand the behaviour of their adolescents and help them even to implicitly develop new parenting skills [Snoek & Horstkötter, 2021] with high levels of support and low levels of controlling behaviours. Additionally, these low levels of controlling behaviours of parents could also be explained by a unique characteristic of adolescence; the adolescents' increasing demand for more autonomy. This demand for autonomy is considered an essential component of an adolescents' development and it enables them to become fully independent adults [Eccles et al., 1991; Smetana, Crean & Campione-Barr, 2005]. The parents' self-reported changes in parenting behaviours based on the understanding of neuroscientific understandings may therefore be positive for the development of their adolescents.

5.3 Limitations and future directions

A number of limitations should be noted with regards to the current study. First, the parents who participated in this study were mostly women with a high level of education. Previous investigations showed that parental education level positively influences educational outcomes [Dubow, Boxer & Huesmann, 2009; Kumar, 2005], while other studies showed the important influence of fathers when parenting a child [Davison et al., 2018]. Therefore, without further research, we cannot generalise our current findings. More work with a larger and more diverse sample is therefore needed to fully understand the role of fathers and of parents with other (educational) backgrounds. Another limitation is that the questionnaire consisted of general questions about adolescent brain development and parenting behaviours. It did not ask parents to answer the questions specifically about one of their own adolescents. This could be an important next step, as experienced parents reported more changes in their parenting behaviour than non-experienced parents. For example, one parent in this investigation remarked the following 'I advise my oldest child but my youngest child needs more explicit guidance'. Parents might change their behaviours based on the different characteristics of their children. Third, our focus was on Dutch parents and therefore more research is needed before generalising these finding on parents in general. An important next step could be to investigate beliefs and behaviours of parents of adolescents in different countries as previous work shown that cultural beliefs and values influence how scientific information is understood and react upon [Ahteensuu, 2011; Suldovsky, 2017]. Fourth, we were unable to identify a relationship between belief in neuromyths and neuroscience literacy and changes in parenting behaviours. However, since the majority of parents did report that they use neuroscientific information, more research is needed to investigate this specific relation, and how findings can be best communicated to parents. Not only should future investigations consider the role of beliefs in neuromyths and neuroscience literacy, but they should also consider other factors that drive the changes in parenting behaviours they reported in the current study, including previous experience with adolescents.

Finally, in our study we focus on self-reported changes mentioned by parents. It is therefore possible that the answers of parents might be biased by social desirability. In order to get a more in-depth view of how parents change their parenting behaviour based on neuroscientific information, future studies should go beyond self-report and combine questionnaires with observations in the home environment or interviews with parents and their adolescent(s).

Conclusion

Our results suggest that on average parents believe a considerable number of neuromyths and show reasonable neuroscience literacy, comparable to previous work with other participant groups [Dekker et al., 2012; Macdonald et al., 2017]. Parents' score on neuroscience literacy is related to educational level and reading neuroscientific articles. Interestingly, parents agree more with negative information about adolescent brain development compared to positive, and a high score on belief in neuromyths relates to these negative views. A large proportion of parents indicated that they have (at some point) changed their parenting behaviours based on their understanding of neuroscientific information, especially when they previously raised an adolescent child. Parents who changed their parenting behaviour have a tendency to focus on changing their own behaviour, and less often focus on how their behaviour might steer or change their child's behaviour. This is needed to give adolescents the opportunity to develop and to become fully autonomous individuals. Our investigation is a first indispensable step to get a better understanding on how neuroscientific information affects parents' views and their parenting behaviours. This accentuates the importance for both parents and scientists to engage in dialogue activities, such as expert discussions and shared working groups on (neuro)scientific investigations. These activities may promote more respectful and trustful relationships between scientists and parents, which subsequently makes communication via either the information deficit model or the dialogue model more effective. It will provide (neuro)scientists with new knowledge from parents and at the same time it will help parents to engage with (neuro)scientific information in more balanced ways when raising their adolescents.

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Disclosure statement

The authors declare that they have no conflict of interest.

Appendix A. Neuromyths and neuroscience literacy questionnaire

The following 20 statements were presented to the participants. In bold are the eight neuromyths. The other twelve statements test the general knowledge on neuroscience. Ten statements were true (T), two were false (F). The answer options were True or False.

1. Boys have bigger brains than girls (T).
2. **We only use 10% of our brain.**
3. The brain can change because of environmental influences, for example by what is learnt at school (T).
4. We use our brains 24 hours a day (T).
5. **People with a dominant left hemisphere are mostly analytical, while people with a dominant right hemisphere are mostly creative.**
6. **The bigger your brain, the smarter you are.**
7. Hormones have an influence on how brains develop (T).
8. Brain development has finished by the time children reach secondary school (F).
9. The brains of boys and girls develop at the same rate (F).
10. **It has been scientifically proven that fatty acid supplements (omega-3 and omega-6) have a positive effect on academic achievement.**
11. Circadian rhythms shift during adolescence causing students to be tired during the first lessons at school (T).
12. Vigorous exercise can improve mental function (T).
13. **Brains of boys and girls are different: therefore boys have more talent for mathematics and science, while girls have more talent for languages.**
14. Production of new connections in the brain can continue into old age (T).
15. The left and right hemispheres of the brain always work together (T).
16. **Learning problems, such as dyslexia, cannot be improved by interventions or training.**
17. **Children are less attentive after consuming sugary drinks and / or snacks.**
18. Extended rehearsal modifies the brains' neural connections (T).
19. Memories are stored in the brain in a network of cells distributed throughout the brain (T).
20. **Neuroimaging techniques can be used to diagnose autism or ADHD.**

Appendix B. Adolescent brain statements

Scientific statements about school and social behaviours during adolescence. Positively framed items are **in bold.** Answer options were from 1 to 5 in which 1 meant 'totally disagree' and 5 'totally agree'.

1. Due to hormonal changes, adolescents often have intense emotions, which they find difficult to properly control.
2. **Adolescents are good at planning and thinking flexibly because their brain is still developing.**
3. Adolescents are worse than adults at adjusting their behaviour within a group because they are more sensitive to social influences.
4. **Adolescents often seek new and exciting experiences due to the continued development of the emotional regions in the brain.**
5. Adolescents are not very good at ignoring irrelevant information and are therefore more easily distracted than adults.
6. **Because adolescents are increasingly able to control their behaviour, they are more frequently able to make well-thought-out choices.**
7. During adolescence, connections and networks in the brain are not yet efficient, which makes complex thought processes difficult.
8. **Adolescents' brains are more flexible than those of adults. As a result, adolescents are more able to learn from their mistakes and adjust their behaviour.**
9. Adolescents' ability to learn is fixed. You have little influence on this, no matter how hard you try.

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