The Teenage Brain: Public Perceptions of Neurocognitive Development during Adolescence

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Abstract

■ Over the past decade, important insights have been obtained into the neurocognitive development during adolescence. To better understand how these neuroscientific insights impact the real world, we investigated how neuroscience has shaped public perceptions of the "teenage brain" and if these perceptions influence adolescent behavior. When asking to generate free associations with the word "teenage brain," adolescents (n = 363, M_{age} = 14.47 years) and parents (n = 164, M_{age} = 47.16 years) more often mention undesirable behaviors (e.g., "irresponsible") than desirable behaviors (e.g., "creative"). Despite these dominantly negative associations, priming adolescents with positively versus negatively framed statements about adolescent brain development did not influence their subsequent risk-taking, impulsivity, and performance on response-to-failure tasks. However, we did find a more nuanced effect, related to how much adolescents agreed with the negative versus positive priming statements: Adolescents' negative beliefs about adolescent brain development reinforced negative behaviors by increased risk-taking behaviors, and adolescents' positive beliefs reinforced positive behaviors by using positive strategies to cope with academic setbacks. The current findings underline the impact of views that build up over time and that these are not easily influenced by a one-time instance of information but rather reinforce the impact of new information. To prevent negative perceptions of the teenage brain from becoming self-fulfilling prophecies, it is important that communication about adolescent neurocognitive development is framed in a more balanced way. Neuroscientists need to be more aware of how their research impacts the real world, before we are fully ready for "real-world neuroscience." ■

INTRODUCTION

Research in the field of cognitive neuroscience has yielded a tremendous amount of insight into the workings of the human brain, including how it develops throughout childhood and adolescence. Recently, attention has shifted to questions about how this information is applicable to our understanding of real-world phenomena such as learning at school, interacting with others, or maladaptive behaviors. This line of exploration is of high importance, because the impact of neuroscientific information entering the public sphere is high (O'Connor, Rees, & Joffe, 2012). O'Connor and Joffe (2013) have gone so far as to suggest that the societal impact of neuroscience is ultimately expressed by the meaning that lay people attach to neuroscientific information in their daily life. However, exploring the real-world relevance of neuroscientific insights is also challenging, as the laboratory environment, jargon, and the many technical steps involved in neuroimaging experiments are extremely difficult to translate and bring closer to a real-life context (van Atteveldt, van Aalderen-Smeets, Jacobi, & Ruigrok, 2014; Schleim & Roiser, 2009). As a consequence, the risk of misconceptions is ever present (Dekker, Lee, Howard-Jones, & Jolles, 2012; Illes et al., 2010). Thus, to address the question whether or not we are ready for "real-world neuroscience," we also need to consider how neuroscience impacts the real world (O'Connor et al., 2012). In this study, we aim to contribute to this important challenge by exploring the effects of disseminated insights from the field of developmental neuroscience and, specifically, the increased understanding of brain development during adolescence. We examine how this knowledge influences the real world, such as lay people's beliefs about the "teenage brain" and the way in which it impacts adolescents' behaviors.

Over the years, adolescence has often been viewed as a period of storm and stress (Hines & Paulson, 2006), characterized by behaviors such as conflicts with parents and increases in risk-taking. The application of neuroimaging research has begun to elucidate how changes in the brain may contribute to these behaviors (e.g., Casey, Tottenham, Liston, & Durston, 2005). One fundamental insight is that

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adolescence is a unique developmental stage, which is characterized by the continued refinement of neural organization, especially in pFC (Mills, Goddings, Clasen, Giedd, & Blakemore, 2014; Crone & Dahl, 2012). However, because adolescence is conceptualized as a distinctive and influential phase in development, it is vulnerable to so-called "neuro-realism"—the use of neuroscience research to objectify and define phenomena (Racine, Waldman, Rosenberg, & Illes, 2010). Combined with the finding that scientific research is more credible when accompanied by (irrelevant) neuroscience findings (Weisberg, Keil, Goodstein, Rawson, & Gray, 2008), it seems that information deriving from developmental neuroscience may confer legitimacy on views of adolescent development. For example, the pattern of protracted neurocognitive development has become mainstream knowledge among parents and teachers (Choudhury, McKinney, & Merten, 2012), which has led to the teenage brain being increasingly used as an explanation for adolescent behaviors (van de Werff, 2017).

As is often the case when translating neuroscientific results to the real world (van Atteveldt et al., 2014), not all nuances have been preserved in this discussion. Consequently, the concept of the teenage brain is often appropriated to warn parents, teachers, and other caregivers about the potential dangers of typical adolescent behaviors, which have been linked to a lack of cognitive control and subsequent increased levels of risk-taking (van de Werff, 2017). In contrast to the negative framing that seems to abound in the public domain, the current direction in developmental neuroscience is to view adolescence as a period of opportunities and possibilities. Recent evidence suggests that, although adolescence is indeed a period of high levels of risk-taking, this also enables increased exploratory behaviors, with usually positive consequences for learning and social interactions (Crone & Dahl, 2012). Thus, the negative narrative that appears to dominate public discourse is an incomplete reflection of current theories.

Framing of knowledge about adolescent brain development is important, as it may impact adolescents' self-concept and behavior (Choudhury et al., 2012). Previous research in other domains has shown that individuals' behaviors can be manipulated simply by modifying others' expectations of their behaviors, even when these expectations are independent of previously observed behaviors (Snyder & Stukas, 1999). These expectations are thought to result in perceptual biases toward the expected behavior as well as self-fulfilling prophecies (Buchanan & Hughes, 2009). Some initial work, based on self-report measures, has been done examining these effects in adolescent samples. These suggest that, when parents hold generalized negative beliefs about adolescents, these beliefs are a stronger determinant of the behavior they expect from their adolescent than the adolescent's actual behavior (Jacobs, Chhin, & Shaver, 2005). Other work has shown that both adolescents and parents' expectations of negative adolescent behaviors (e.g., risk-taking) are predictive of the subsequent incidence of these behaviors (Buchanan & Hughes, 2009). More recently, Qu, Pomerantz, Wang, Cheung, and Cimpian (2016) demonstrated that many American teenagers view adolescence as a period characterized by a decreased responsibility to parents and family, in contrast to an increased importance of peer relationships. Adolescents also reported reduced engagement in school compared with younger children. These lower expectations of familial responsibility and school engagement predicted decreases in independent learning over the course of a school year. These studies suggest that certain behaviors that are considered normative in adolescence may shape both expectations and actual behaviors (Qu et al., 2016).

In light of the danger of neuro-realism as described above, the impact of stereotypical views about adolescent behavior and development may be especially negative if aspects such as brain immaturity, lack of impulse control, and increased risk-taking are continuously emphasized when referring to the teenage brain. However, adolescents and parents' current perspectives on the teenage brain, and the influence of positively or negatively framed scientific information on actual adolescent behaviors instead of its influence on self-reported behaviors, have not been studied. By defining adolescence as a period when the brain is too immature to enable performance of certain tasks (e.g., planning schoolwork) or particular behaviors (e.g., refraining from dangerous activities), the "immature teenage brain" may be viewed as the cause of this suboptimal behavior. This could reinforce the amount of undesired behaviors in adolescents, or at least provide a legitimate excuse for showing it, rather than encouraging improvement of the cognitive function or behavior in question. In contrast, a greater influence of positive framing, for example, by focusing on greater flexibility and learning possibilities, may lead to a more positive impact on public discourse and on the behavior and self-conceptions of adolescents.

In this study, we aim to study the effect of neuroscience information about adolescent brain development on public perceptions of the teenage brain and experimentally measured adolescent behaviors. First, we examined Dutch adolescents and parents' perspectives on the teenage brain.[1] To this end, we first addressed the question whether adolescents and parents of adolescents' perspectives of the teenage brain are predominantly positive or negative. More specifically, we investigated (a) which spontaneous associations adolescents and parents have with the word "teenage brain," (b) which associations adolescents think adults have with "teenage brain," and (c) which associations parents think their adolescent child has with this popularized term. On the basis of previous studies showing that the lay message about the teenage brain often focuses on the negative aspects of adolescence (Choudhury et al., 2012), we hypothesized that both adolescents and parents would list negative associations more frequently than positive associations. Furthermore, because of the origin of the Dutch translation of the word "teenage brain," we hypothesized that both (stereotypical) adolescent behaviors as well as brain-specific associations would be mentioned.

Second, we examined how activation of positive or negative views of adolescence influenced subsequent behavior. Adolescents were presented with either positively or negatively framed scientific statements about the influence of neurocognitive development on adolescent behavior. Previous work has shown that exposure to self-relevant information, such as responding to statements, can activate views about stereotypes and can influence subsequent behavior (e.g., Bry, Follenfant, & Meyer, 2008; Moè & Pazzaglia, 2006). In the example study of Bry et al. (2008), participants were asked to complete a questionnaire that focused on either independent or interdependent views of the self. This is in line with previous work that has shown that behaviors can be changed by increasing accessibility to specific knowledge through priming (see, e.g., Wheeler & Petty, 2001). Following these previous studies that used exposure to self-relevant information to prime stereotypical beliefs, we used negatively and positively framed statements to activate either positive or negative beliefs about the developing adolescent brain. After indicating their agreement with the statements, the participants performed a number of tasks aimed to assess typical behaviors in adolescence: a risk-taking task, an impulsivity task, and a response-to-failure task. We first analyzed task performance using the priming as a categorical (between-subject) independent variable and hypothesized that the negatively (vs. positively) framed information about the adolescent brain would increase risk-taking and impulsivity and decrease resilience to academic challenges and setbacks. Second, to get a more nuanced picture of how prior beliefs about the adolescent brain relate to the performed tasks, we correlated the Likert scores on the statements with task performance separately for each of the priming groups. As previous studies indicate that there might be gender differences in adolescents' risk-taking behaviors (Felton, Gibson, & Sanbonmatsu, 2003) and cognitive impulsiveness (Frederick, 2005), suggesting that boys show more risk-taking behaviors and less cognitive impulsivity compared with girls, we included sex as a covariate in our analyses. No sex differences were found in responses to academic failure (Blackwell, Trzesniewski, & Dweck, 2007), and therefore sex was not included as a covariate.

The results of our study might increase insights into how neuroscientific knowledge influences adolescents'

Table 1. Descriptive Statistics of Age, Sex, and Educational Level for Parents (n = 164) and Adolescents (n = 363)

	Parents			*Adolescents*	
	Male (n = 32)	*Female (n = 131)*	*Unknown (n = 1)*	*Male (n = 171)*	*Female (n = 192)*
Age (in years)					
Mean (*SD*)	48.5 (5.1)	46.9 (4.0)	45.0	14.5 (1.0)	14.4 (0.9)
Range	38–59	35–58	–	11.9–16.7	12.2–16.8
Unknown	6.3%	1.5%	–	7.0%	1.6%
Highest completed educational level					
Primary school	–	1.5%	–	–	–
High school	6.3%	6.9%	100.0%	–	–
MBO	9.4%	19.8%	–	–	–
HBO	34.4%	45.1%	–	–	–
WO	50.0%	26.7%	–	–	–
Number of children in the family					
Mean (*SD*)	2.7 (1.0)	2.3 (0.8)	2.0 (–)	–	–
Age range of children	4–23 years	2–28 years	10–13 years	–	–

The Dutch schooling system after high school is divided into MBO (middelbaar beroepsonderwijs), which is focused on vocational training, and two types of higher education—HBO (hoger beroepsonderwijs, i.e., university of applied science) 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.

real-world beliefs and behaviors and thereby highlight the importance of incorporating real-world perspectives in responsibly moving toward "real-world neuroscience."

METHODS

Main Study

Participants

Three hundred sixty-five adolescents from four schools in the north of the Netherlands and 193 parents or caregivers of other adolescents between 11 and 18 years old (secondary education) participated in this study. If a participant completed the full questionnaire but had missing responses for a particular measure, the participant was excluded in the analyses for that particular measure and was included in the other analyses. Data of two adolescents were removed because they did not finish the questionnaire. Furthermore, 29 parents did not provide their associations with the teenage brain and were therefore excluded from our data set. The analyses were conducted with 363 adolescents

Table 2. Descriptions and Examples of the Codes That Were Used in Analyzing Adolescents and Parents' Associations with the Teenage Brain and the Percentages of the Mentioned Associations

Code	*Description*	*Example(s)*	*A (%)*	*AP (%)*	*P (%)*	*PA (%)*
Behavior	Associations that refer to specific behaviors during adolescence and/or specific activities that are undertaken by adolescents		28.87	53.11	55.94	51.99
Desirable behavior	Behavior that is considered to be desirable in social situations	"Independent," "responsible," "kind," "creative"	3.12	3.54	5.12	5.62
Boundary searching behavior	Behavior indicating that the adolescent is trying out new things (without showing boundary crossing or disturbing behavior)	"Discover the world," "stubborn," "doing their own thing," "experimenting" (with drugs, alcohol)	4.23	8.58	10.45	14.05
Undesirable behavior	Behavior that is considered to be undesirable or disturbing in social situations or behavior that might impair others	"Irritating," "cranky," "lazy," "rude"	15.9	37.66	35.86	27.63
Neutral behavior	Behavior that cannot be categorized as either desirable, boundary searching, or undesirable and/or is unspecified	"Behavior," "thinking," "behavior of adolescents"	5.53	2.25	3.07	0.94
Behavior of parents	Specific behavior of parents to cope with their teenage children or how adolescents perceive their parents' behavior	"It's a challenge," "difficult parent," "rules that make no sense"	0.10	1.07	1.43	3.75
Development	Associations that refer to the development of the teenage brain and/or developments that take place during adolescence	"Developing," "brain in development," "growing"	11.67	9.12	19.26	9.60
Synonyms	Associations having the same or nearly the same meaning as the teenage brain or associations that use (parts of) the concept of the teenage brain	"Brain," "adolescent," "adolescent brain"	28.97	12.12	3.28	3.28
Miscellaneous		"Meetings," "book," "presentation"	30.48	25.64	21.52	35.13

A = associations adolescents have; AP = associations adolescents think parents have; P = associations parents have; PA = associations parents think adolescents have.

(52.9% female) and 164 parents (79.9% female; see Table 1).

Measures

Associations with the teenage brain. In the first part of the questionnaire, we asked adolescents to name the first three spontaneous associations that came to mind when thinking about the teenage brain. Adolescents needed to provide three typed answers in different boxes. Furthermore, we asked the adolescents to fill in the first three associations when thinking about what adults, like their parents and teachers, might think about the teenage brain. In addition, we asked participating parents/caregivers to name their first three associations with the teenage brain and what they thought that their teenage children might associate with the teenage brain (see Table 2 for an overview). All in all, we distinguished four groups of associations: (1) associations adolescents have with the word "teenage brain" (A), (2) associations adolescents think adults have with teenage brain (AP), (3) associations parents have with the word "teenage brain" (P), and (4) associations parents think their adolescent has with the teenage brain (PA).

Priming statements. We examined whether priming by neuroscientific statements influenced adolescents' behaviors by comparing the task results of adolescents in three different priming conditions: (1) positively framed statements (positive condition), (2) negatively framed statements (negative condition), and (3) no statements before the tasks (neutral condition). Every statement covered the same topic in both conditions but was either negatively or more positively framed. We included a broad variety of adolescent stereotypes in the set of statements, such as being emotionally driven, struggling with planning, and reduced behavioral control, resulting in nine statements covering the most common stereotypes (see Table 3). Because negative adolescent stereotypes are more common, the negatively framed statements were used as a starting point, and we then reformulated the statements with less emphasis on negative aspects to create positive versions covering the same core concepts. The participants had to indicate whether they agreed or disagreed with the statements on a 5-point Likert scale

Table 3. Scientific Statements about School and Social Behaviors during Adolescence, Framed Positively, Negatively, or Both

Positive Framing Condition	*Negative Framing Condition*
1. Due to hormonal changes, adolescents often experience intense emotions that influence their behavior.	**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.	2. Because their brains are still in development, many adolescents struggle to plan their activities.
3. Adolescents are better than adults at adjusting their behavior within a group because they are more sensitive to social influences.	**3. Adolescents are worse than adults at adjusting their behavior 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.	4. Adolescents often display irresponsible and risky behaviors because their emotional brain areas are still developing.
5. Adolescents are good at ignoring irrelevant information and are therefore less quickly distracted than adults.	**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 behavior, they are more frequently able to make well-thought-out choices.	6. Because adolescents have less control over their behavior than adults, they often make impulsive choices.
7. During adolescence, connections in the brain become increasingly efficient, facilitating more complex thought processes.	**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 behavior.	8. Adolescents' brains are less flexible than those of adults. As a result, they are less able to learn from their mistakes and adjust their behavior.
9. Your ability to learn can change. As an adolescent, you can influence this by doing your best.	**9. Adolescents' ability to learn is fixed. You have little influence on this, no matter how hard you try.**

Numbers represent the order in which the adolescents received the statements. Adolescents in the neutral condition received the statements represented in bold in the same order.

(1 = *totally disagree*, 5 = *totally agree*). Participants in the positive and negative conditions completed the statements before the tasks; participants in the neutral condition, after the tasks (see Procedure).

Balloon analogue risk task. The Balloon Analogue Risk Task (BART; Lejuez, Aklin, Zvolensky, & Pedulla, 2003) provides a measure of risk-taking behavior in which participants had to inflate a balloon. The further the balloon was inflated, the more points the participant received. However, if the balloon burst, no points were earned for that trial. The participant could choose how far to inflate the balloon by selecting the number of desired pumps on a slider (minimum [min] = 0, maximum [max] = 128). Then, the participant was shown whether or not the balloon had burst and whether or not he or she had earned points for that round (see Figure 1). This process was repeated 30 times.

The absolute scores of the BART were used in subsequent analyses, meaning that the number of pumps that an adolescent chose on the slider was used, without taking the explosion of the balloon into account. Previous work has shown this to be a more accurate estimation of adolescents' risk-taking behaviors (Pleskac, Wallsten, Wang, & Lejuez, 2008).

Cognitive reflection test. The Cognitive Reflection Test (CRT; Frederick, 2005) questionnaire measures impulsivity to cognitive responses using three relatively easy mathematical questions. However, to answer correctly, an individual needs to suppress the erroneous answer that immediately comes to mind and think again to provide the correct answer. The items that were used were slightly adapted to better match to the participants' age, but the content was similar to the original items (see Table 4). Participants' score on the CRT was determined by the number of correct answers, ranging from 0 to 3. Afterward, participants were categorized into three groups: low (0 point), intermediate (1–2 points), or high (3 points) CRT group (following Frederick, 2005).

Response-to-failure task. This questionnaire (Blackwell et al., 2007) provides a measure of response to failure based on a scenario followed by nine questions. The scenario that was used was as follows: "Imagine: You start a new class in mathematics at the beginning of the year and you really like the subject and the teacher. You think you know the subject pretty well, so you study a medium (not much, but also not little) amount for the first quiz. Afterwards, you think you did okay, even though there were some questions you didn't know the answer to.

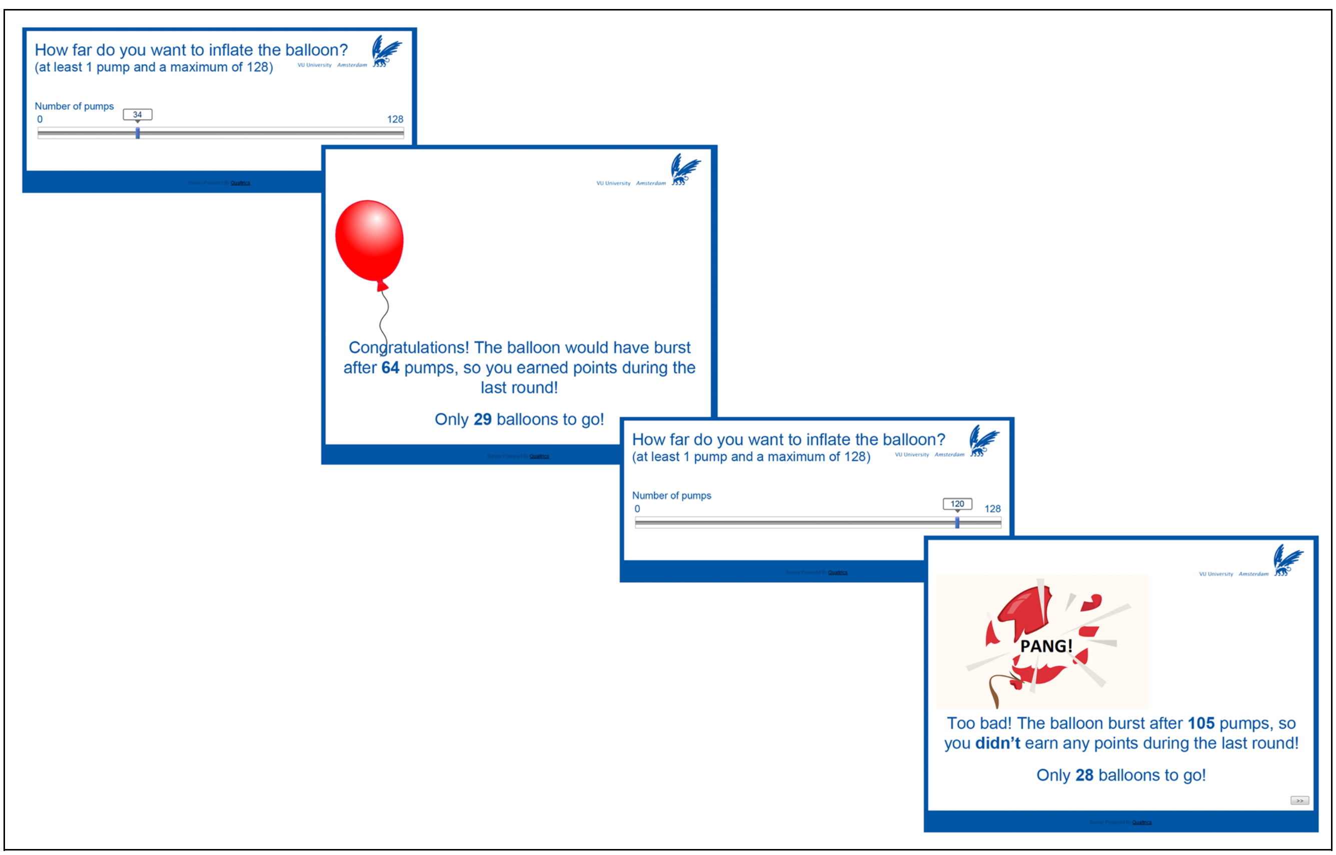

Figure 1. Display of the sequence of the risk-taking task (BART). Adolescents had to inflate a balloon (30 times) by selecting the number of desired pumps on a slider (min = 0, max = 128) and could earn more points when the balloon was further inflated, but no points were earned if the balloon burst. On the basis of the selected number of desired pumps, it was shown whether or not the adolescent had earned points and the balloon had burst.

Table 4. Differences of CRT Items

Original Items	*Adapted Items*
1. A bat and a ball cost \$1.10 in total. The bat costs \$1.00 more than the ball. How much does the ball cost? _____ cents	1. A ball and a whistle cost €1.10 in total. The ball costs €1.00 more than the whistle. How much does the whistle cost? _____ cents
2. If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets? _____ minutes	2. If it takes 5 machines 5 minutes to make 5 cakes, how long would it take 100 machines to make 100 cakes? _____ minutes
3. In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake? _____ days	3. There are flowers growing in a field. Every day, the number of flowers doubles. If it takes 48 days for the flowers to cover the entire field, how long would it take for the flowers to cover half of the field? _____ days.

Then the class gets their quizzes back and you find out your score: you only got a 4. What would you think and what would your initial reaction be?" Please note that, in Dutch, tests are marked on a scale from 1 to 10, so a "4" means a failed test. Participants indicated whether they agreed with each statement presented after the scenario on a 6-point Likert scale (1 = *strongly disagree*, 6 = *strongly agree*). The questionnaire consists of two subscales: Helpless Attributions (HA; four items, e.g., "I wasn't smart enough") and Positive Strategies (PS; this subscale is a combination of the items of Positive Effort (PE)-based strategies [two items, e.g., "I would work harder on math from now on"] and the recoded items of Negative Effort (NE)-avoidant strategies [three items, e.g., "I would spend less time on math from now on"], and a mean score is calculated).

We started with these a priori subscales; however, because we used a Dutch translation and the subscales showed mediocre internal consistency (HA: $\omega = .56$, greatest lower bound [GLB] = .57, Cronbach's $\alpha = .55$; PS: $\omega = .64$, GLB = .74, Cronbach's $\alpha = .63$), we used principal component analysis (PCA) with varimax rotation to further inform us about the best structure of the items and subscales (see Table 5). The scree plot of the PCA showed that using three factors was optimal. The PE items and one NE item loaded on the first component: PE1, PE2, and NE2. We therefore used these three items for the revised subscale PS (with NE2 recoded). The second factor included three of the HA items (HA1, HA2, and HA4) and one NE item (NE1). Therefore, we included HA1, HA2, NE1, and HA4 in the second factor creating the revised subscale HA. The third factor included NE3 and HA3 and seems to measure thoughts and feelings specific to the (hypothetical) math examination. However, this subscale was not used in further analyses because of low internal consistency.

Procedure

The parents or caregivers of the adolescent participants received an information letter about the study and had to indicate if they did not wish for their child to participate (passive consent). If the adolescent could participate in our study, he or she received information about the study and gave informed consent before testing. Participants were tested in groups in a quiet room in their school. Each participant was randomly assigned to one of three priming conditions (i.e., positive, negative, or neutral) by a number. Boys and girls were equally distributed among conditions. Participants received a link to the questionnaire and completed the questionnaire by themselves. The questionnaire started with the free associations (same for all conditions). Next, participants assigned to the positive or negative priming condition indicated their agreement on nine statements and subsequently performed behavioral tasks: BART, CRT, and response-to-failure task. Participants assigned to the neutral condition answered the statements (alternately positively and negatively framed statements; see Table 3) after finishing the

Table 5. Factor Loadings, Item Numbers, and Cronbach's Alphas of the Subscales Used for Response to Failure Based on PCA with Varimax Rotation

Factor	*Loading*	*Item Number*	*Cronbach's α*	*ω*	*GLB*
HA			.63	.65	.66
	.73	HA1			
	.80	HA2			
	.48	HA4			
	.61	NE1			
PS			.70	.75	.78
PE-based strategies	.88	PE1			
	.86	PE2			
NE-avoidant strategies	−.58	NE2			

Items NE3 and HA3 were excluded for the further analyses, because the internal consistency was low, Cronbach's $\alpha = .47$. Item NE2 was recoded for further analyses. Kaiser–Meyer–Olkin = .70. Bartlett's test of sphericity, χ^2 (36) = 560.43, $p < .001$. GLB = greatest lower bound.

tasks to ensure that the total measurement length was equal for all groups (as they were in the same room). Participants read a debriefing letter after they completed the questionnaire and were thanked for their participation.

Participating parents received a digital information letter in their mailbox and could provide their consent actively online through an Internet link. The questionnaire followed directly after the informed consent. This questionnaire started with the free associations, which is the only part that was included in this study. All procedures were approved by the ethics committee of the Faculty of Behavioural and Movement Sciences, Vrije Universiteit Amsterdam.

Analyses

Associations with the teenage brain. All associations were inserted and coded in ATLAS.ti Version 7.5.18 (1993–2017). Because "teenage brain" is often used to warn parents, teachers, and other caregivers about the potential dangers of typical adolescent behaviors (van de Werff, 2017), coding of associations was mainly focused on behavioral associations. On the basis of everyday conceptions of how lay people talk about the teenage brain (i.e., immature, lacking cognitive abilities, refinement of the brain), and after a first exploration of our data set, we developed a coding scheme (see Table 2). Codes were not used or seen by the participants themselves; they were only used to label participants' associations post hoc. Five different categories of behavioral associations were used to code the associations in our data set: (1) desirable behavior: behavior that is considered to be desirable in social situations, for example, "responsible"; (2) boundary searching behavior (or trying new things): behavior indicating that the adolescent is trying out new things (without showing boundary crossing or disturbing behavior), for example, "discover the world"; (3) undesirable behavior: behavior that is considered to be undesirable or disturbing in social situations or behavior that might impair others, for example, "selfish"; (4) neutral behavior: behavior that cannot be categorized as either desirable, boundary searching, or undesirable behavior and/or behavior that is unspecified, for example, "behavior"; and (5) adult behavior: specific behavior of parents to cope with their teenage children or how adolescents perceive their parents' behavior, for example, "be strict." In coding our data, we used the following set of criteria to determine whether or not a respondent's association would qualify as an association that was related to behavior: (a) The association describes an activity of an individual that is observable by others, for example, "mood swings"; (b) the association refers to a behavioral action, for example, "(to) party"; or (c) the association refers to consumption of products, for example, "alcohol." Next to associations related to specific behaviors during adolescence, we also coded our data for associations related to the development of the teenage brain or changes that take place during adolescence and associations that were merely synonyms of the teenage brain (see Table 2).

All data were coded by the first author. To establish the interrater reliability of our coding scheme, 20% of the data were randomly selected to be independently scored by a second rater. With a Cohen's κ of .87, the interrater reliability was found to be almost perfect (McHugh, 2012; Landis & Koch, 1977).

Differences in adolescents and parents' perspectives of the teenage brain were analyzed in two steps. First, we calculated percentages of adolescents and parents' associations with the teenage brain for the different categories of our coding scheme (see Table 2) to get an overview of the associations in each group (i.e., A, AP, P, and PA). Next, we analyzed differences in the associations between groups using chi-square tests. In line with our research question and guided by the codes we assigned to our data, we analyzed differences in associations between groups that were related to different types of behavior and development.

Priming statements and tasks. The analyses were conducted as follows: First, differences in mean scores on the statements between the group who indicated agreement with positive statements and the group who indicated agreement with negative statements were examined. Using an independent *t* test, we compared the mean score of agreement toward positively framed statements with the mean score of agreement toward negatively framed statements.

Second, we analyzed whether receiving positively or negatively framed information about adolescent brain development influenced overall task performance by using the priming condition as a categorical variable (positive, negative, or no information). On the basis of previous literature, we included sex as a covariate when examining risk-taking behaviors (Felton et al., 2003) and impulsivity behaviors (Frederick, 2005). We conducted an ANCOVA for the BART, a chi-square test for the CRT and a MANOVA for the response-to-failure task.

Third, to get a more nuanced picture of the relation between participants' beliefs about adolescent brain development and their task performance, we examined whether the level of agreement with the statements (mean agreement score) was related to participants' performance on the three tasks. These analyses were conducted separately for participants who had to indicate their agreement with positive statements and for participants who had to indicate their agreement with negative statements. Because participants in the neutral condition received the statements after the tasks, they were excluded from these analyses. We used multiple linear regression models to analyze the influence of agreement with the statements on the BART and on the response-to-failure task and a multinomial logistic regression for the

CRT. All analyses were corrected for multiple comparisons (false discovery rate [FDR]; Benjamini & Hochberg, 1995).

In the first and third analyses described above, we used Likert scale scores on the priming statements. According to some researchers (e.g., Jamieson, 2004), nonparametric tests would be better suited to analyze Likert scale scores, because they provide ordinal data. However, parametric tests are more robust than nonparametric tests (Sullivan & Artino, 2013) and can be used with Likert scale scores, even when assumptions are violated (Norman, 2010).

Supplemental Study

Aims

To ensure the specificity of the found associations to adolescent brain development (rather than to adolescent behavior more generally), an extra questionnaire was acquired post hoc in a new sample of 252 adolescents. The aim of this supplemental study was to examine whether the findings of our original study were specific to (1) adolescent brain development rather than adolescence in general (Part 1) and (2) adolescence as a specific developmental period compared with childhood (Part 3). Furthermore, this study was also used to (3) validate the positive versus negative valence of the priming statements that were used in the original study (Part 2).

Participants

Two hundred fifty-two Dutch adolescents from four schools in the Netherlands were recruited as a new sample for our supplemental study (47.6% female; M_{age} = 13.8 years, SD_{age} = 1.10 years, Unknown_{age} = 13.1%). If a participant completed the full questionnaire but had invalid data for a particular measure, the participant was excluded in the analyses for that particular measure but was included in the other analyses.

Procedure

Participants of the new sample were randomly assigned to one of two versions of the questionnaire. Boys and girls were equally distributed among conditions. The questionnaire was divided into three parts, in which Parts 1 and 3 were the same in both versions. In the first part, the participants had to indicate to what extent they thought that the listed adolescent behaviors are a consequence of the developing brain. Next, in the second part, the participants scored nine statements, randomly taken from the positively or negatively framed priming conditions in the original study, and indicated whether they thought that the statement was a positive or negative description of adolescent behavior. In the third part, participants indicated whether the different types of behavior, as mentioned in the positively and negatively framed statements in the second part, were more common during childhood or adolescence or was equally common during childhood and adolescence.

Measures

Questionnaire. We used two versions of the questionnaire, in which only Part 2 differs between versions. The framing of the statements was intermixed; four or five statements were positively framed, and the other four or five statements were negatively framed (see also Table 6). The two versions of the new questionnaire were randomly distributed among the 252 participants (n = 128 in Version 1, n = 124 in Version 2). In Parts 1 and 2 of the questionnaire, adolescents had to indicate on a 5-point Likert scale to what degree their opinion corresponds to the statement (Part 1) or how positive/negative they thought the statements were (Part 2). In Part 3, adolescents had to choose the statement (of three options) they agreed with most (see Table 6 for an overview of the questionnaires used).

Part 1. To maximize the connection to the original data, we used one reported association from each of the categories "undesirable" (rebellious or disobedient behavior), "boundary searching" (stubborn), and "desirable" (eager to learn). In total, nine participants had incomplete data for these three questions and were therefore excluded from the analyses (N = 243 adolescents; female = 47.3%; M_{age} = 13.8 years, SD_{age} = 1.10 years, Unknown_{age} = 12.8%).

Part 2. The statements were randomly taken from the positively or negatively framed priming conditions in the original study. Of the 252 adolescents, 10 adolescents did not complete this second part of the questionnaire, resulting in 242 adolescents (female = 47.5%; M_{age} = 13.8 years, SD_{age} = 1.10 years, Unknown_{age} = 13.2%).

Part 3. Of the 252 adolescents who participated in this study, 29 adolescents did not complete this item, resulting in 223 participants (female = 48.4%; M_{age} = 13.8 years, SD_{age} = 1.09 years, Unknown_{age} = 12.6%).

RESULTS

Main Study

Perspectives on the Teenage Brain

Adolescents reported 994 associations with the teenage brain (A) and 932 associations with what they thought adults (such as their parents and teachers) would think about the teenage brain (AP). Parents reported 488 associations with the teenage brain (P) and 427 associations with what they thought their teenage children would think about the teenage brain (PA). Percentages of

Table 6. Questionnaire of the Supplemental Study

Part 1 (equal for both versions)

Tick the box which corresponds to your opinion on each of the statements below

	Not at all [1]	[2]	[3]	[4]	Completely [5]
Adolescents sometimes show rebellious or disobedient behavior. To what extent is this behavior the consequence of their brain still maturing?	○	○	○	○	○
Adolescents are sometimes stubborn. To what extent is this behavior the consequence of their brain still maturing?	○	○	○	○	○
Adolescents are sometimes eager to learn. To what extent is this behavior the consequence of their brain still maturing?	○	○	○	○	○

Part 2 (differs between versions)

On the reverse of this page, you will see a number of statements. For each statement, you can indicate whether you think it is a positive or a negative description of adolescent behavior.

Version 1	Version 2	Very Positive	Slightly Positive	Not Positive and Not Negative	Slightly Negative	Very Negative
Due to hormonal changes, adolescents often experience intense emotions that influence their behavior.	Due to hormonal changes, adolescents often have intense emotions which they find difficult to properly control.	○	○	○	○	○
Adolescents are good at planning and thinking flexibly because their brain is still developing.	Because their brains are still in development, many adolescents struggle to plan their activities.	○	○	○	○	○
Adolescents are worse at adjusting their behavior within a group than adults because they are more sensitive to social influences.	Adolescents are better at adjusting their behavior within a group than adults because they are more sensitive to social influences.	○	○	○	○	○

Adolescents often seek new and exciting experiences due to the continued development of the emotional regions in the brain.	Adolescents often display irresponsible and risky behaviors because their emotional brain areas are still developing.	○	○	○	○	○
Adolescents are not very good at ignoring irrelevant information and are therefore more easily distracted than adults.	Adolescents are good at ignoring irrelevant information and are therefore less quickly distracted than adults.	○	○	○	○	○
Because adolescents have less control over their behavior than adults, they often make impulsive choices.	Because adolescents increasingly gain control over their behavior, they are more frequently able to make well-thought-out choices.	○	○	○	○	○
During adolescence, connections and networks in the brain are not yet efficient, which makes complex thought processes difficult.	During adolescence, connections in the brain become increasingly efficient, facilitating more complex thought processes.	○	○	○	○	○
Adolescents' brains are more flexible than those of adults. As a result, adolescents are more able to learn from their mistakes and adjust their behavior.	Adolescents' brains are less flexible than those of adults. As a result, they are less able to learn from their mistakes and adjust their behavior.	○	○	○	○	○
Your ability to learn can change. As an adolescent, you can influence this by doing your best.	Adolescents' ability to learn is fixed. You have little influence on this, no matter how hard you try.	○	○	○	○	○

Part 3 (equal for both versions)

Again, give your opinion by ticking one box.

The different types of behavior as described in Part 2 are:

o More common during childhood compared with adolescence

o Equally common during childhood and adolescence

o More common during adolescence compared with childhood

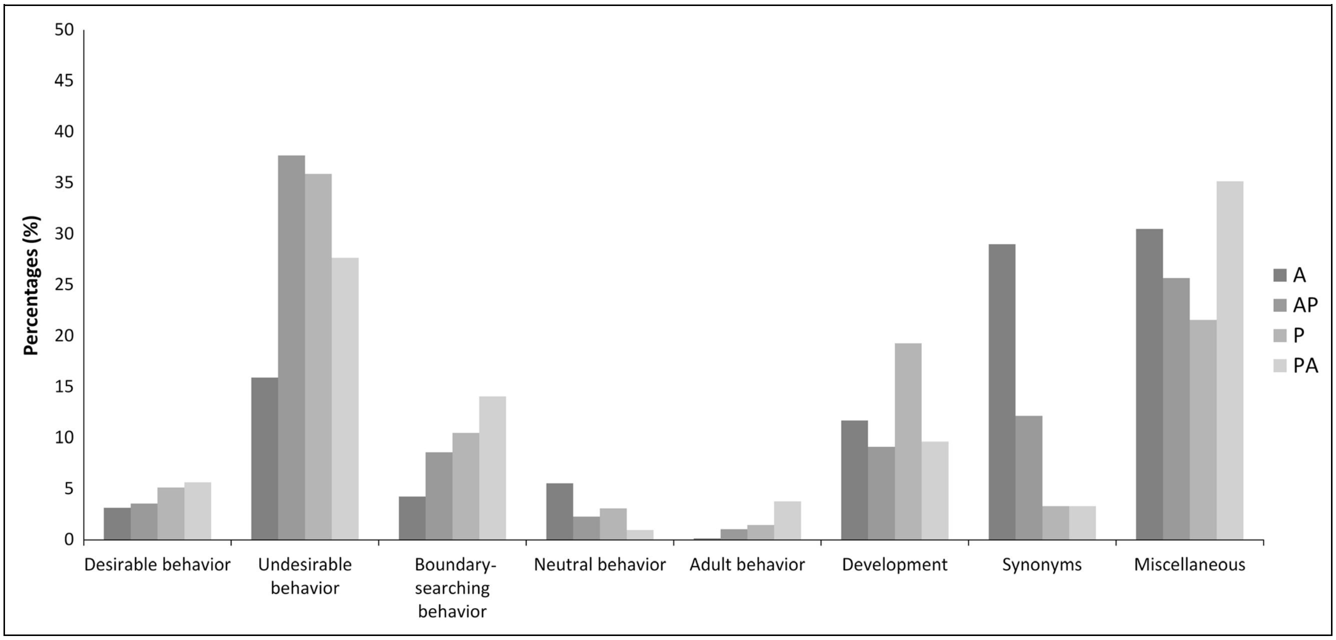

Figure 2. Percentages of adolescents and parents' associations with the teenage brain. Undesirable behavior is mostly mentioned by both adolescents and parents. A = adolescents' association with the word "teenage brain"; AP = adolescents' thoughts of adults' association with the teenage brain; P = parents or caregivers' association with the word "teenage brain"; PA = parents or caregivers' thought of the association of their child with the teenage brain.

responses per coding category are shown in Table 2 and Figure 2.

To examine differences between adolescents and parents' associations with the teenage brain, we conducted several chi-square tests. Although there were similarities in adolescents and parents' associations, we found some interesting differences as well. First, analyses showed that parents reported significantly more undesirable behaviors when thinking about the teenage brain compared with adolescents (P vs. A), $\chi^2(1) = 74.89$, $p < .001$. Besides, adolescents also thought their parents would associate the teenage brain with undesirable behaviors more frequently than they did themselves (AP vs. A), $\chi^2(1) = 117.20$, $p < .001$. Moreover, in our data set, the teenage brain was mostly associated with behavior that is undesirable (802 associations vs. 113 desirable behavior associations). Next to the low total number of associations related to desirable behavior, adolescents and parents did not differ in the number of reported associations related to this behavior (A vs. P), $\chi^2(1) = 3.62$, $p = .06$. When comparing adolescents and parents' associations that were related to boundary-searching or risk-taking behavior, results indicated that parents associated the teenage brain more frequently with this type of behavior than adolescents (P vs. A), $\chi^2(1) = 21.57$, $p < .001$. Interestingly, adolescents hardly associated the teenage brain with parenting behavior (one association), whereas parents reported 14 associations related to parents' behavior (P vs. A), $\chi^2(1) = 28.88$, $p < .001$. Finally, parents more frequently associated the teenage brain with adolescent development than adolescents (P vs. A), $\chi^2(1) = 15.51$, $p < .001$. However, there was no difference in the frequency of associations coded as "development" when comparing what adolescents thought their parents would associate and what parents thought their teenage children would associate with the teenage brain (PA vs. AP), $\chi^2(1) = 0.08$, $p = .78$.

Furthermore, we examined adolescents' perspectives on the teenage brain using their agreement with positively and negatively framed statements. Differences in mean scores (1.0 = *totally disagree* to 5.0 = *totally agree*) between the group who received positively framed statements (n = 120) compared with the group who received negatively framed statements (n = 121) were examined with an independent t test. On average, participants who received negatively framed statements agreed less with the statements ($M = 2.73$, $SE = 0.06$) compared with participants who received positively framed statements ($M = 3.20$, $SE = 0.05$). This difference, −.47, BCa 95% CI [−0.62, −0.33], was significant, $t(239) = -6.54$, $p < .001$, with a medium effect size, $d = .77$.

Effect of Priming on Risk-taking Behavior

First, before we examined the effect of priming on risk-taking behavior during the BART, we excluded eight participants (50% female, $M_{age} = 15.3$ years, $SD_{age} = 0.9$ years) who had more than one missing trial. Therefore, 355 participants (53% female, $M_{age} = 14.5$ years, $SD_{age} = 1.0$ years) were included for the analyses on risk-taking behavior (see Table 7 for the descriptive statistics).

An ANCOVA of Priming Condition (positive, negative, and neutral) × BART mean score with Sex as a covariate was conducted to examine whether receiving priming

Table 7. Descriptive Statistics (Min, Max, Mean, and *SD*) of the BART, Separately for Boys (n = 167) and Girls (n = 188), and the Total Group (n = 355)

	Mean Number of Pumps			*Points*			*Number of Explosions*		
	Min	*Max*	*Mean (SD)*	*Min*	*Max*	*Mean (SD)*	*Min*	*Max*	*Mean (SD)*
Boys	4.20	110.07	53.80 (18.45)	126	1,561	685.78 (193.82)	0	24	12.75 (4.63)
Girls	2.13	81.10	49.13 (16.68)	64	1,447	687.59 (195.42)	0	22	11.57 (4.21)
Total	2.13	110.07	51.33 (17.66)	64	1,561	686.74 (194.40)	0	24	12.13 (4.44)

by neuroscientific information influenced overall task performance. This resulted in a main effect of Sex, $F(2, 351) = 1.89$, $p = .02$, $\eta^2 = .02$, but no main effect of Priming condition, $F(2, 351) = 1.98$, $p = .15$, observed power = .39.

Finally, to examine whether participants' agreement toward the positively or negatively framed statements influenced risk-taking behavior during the task, a linear regression analysis (with mean agreement score and sex) was conducted per priming condition. For the negative statements, the regression model with mean agreement score had the best model fit, and therefore only the results of the first model will be reported. A significant effect of agreement score on risk-taking behavior was found in participants who indicated their agreement with the negative statements, $b = 7.87$ [2.73, 13.02], $p < .01$, suggesting that participants who agreed more with the negative statements (i.e., who believe that the developing adolescent brain has negative consequences) showed higher levels of risk-taking behavior. For the positive statements, all regression models did not predict risk-taking behavior (see Table 8 for a complete overview).

Effect of Priming on Impulsivity

Before analyzing the effect of priming statements on cognitive impulsivity, we excluded one participant because of incomplete data, and analyses were performed with 362 participants.

Using a chi-square test for boys (n = 170) and girls (n = 192) separately, we examined whether priming condition (positive, negative, and neutral) influenced CRT scores

Table 8. Linear Model of Priming Effect on Risk-Taking Behavior, Separated by Priming Condition (Negative: n = 119 and Positive: n = 119), Corrected for Multiple Comparisons (FDR)

	Negative Priming Condition				*Positive Priming Condition*			
	b	*SE b*	*β*	*p*	*b*	*SE b*	*β*	*p*
Model 1								
Constant	29.06	7.26		**<.001**	50.62	9.05		**<.001**
Mean priming score	7.87	2.59	.27	**<.01**	1.18	3.18	.03	.71
Model 2								
Constant	31.62	7.85		**<.001**	52.92	9.09		**<.001**
Mean priming score	7.48	2.64	.26	**<.01**	1.28	3.15	.04	.69
Sex	−2.79	3.24	−.08	.39	−5.16	3.09	−.15	.10
Model 3								
Constant	34.09	11.65		**<.01**	39.15	12.12		**<.01**
Mean priming score	6.61	4.01	.23	.10	6.21	4.26	.18	.15
Sex	−7.02	15.04	−.20	.64	24.78	17.88	.74	.17
Interaction Priming × Sex	1.54	5.34	.12	.77	−10.66	6.27	−.92	.09

For the negative priming condition, $R^2 = .07$ for Model 1, $R^2 = .08$ for Model 2, and $R^2 = .08$ for Model 3; for the positive priming condition, $R^2 = .001$ for Model 1, $R^2 = .03$ for Model 2, and $R^2 = .05$ for Model 3.

Significant models after FDR correction for multiple comparisons (with an α level = .05) are shown in bold.

Table 9. Descriptive Statistics (Min, Max, Mean, and *SD*) for the Two Response-to-Failure Subscales, for Boys (n = 165) and Girls (n = 181) Separately and the Total Group

	Helpless Attributions			*Positive Strategies*		
	Min	*Max*	*Mean (SD)*	*Min*	*Max*	*Mean (SD)*
Boys	1.00	6.00	2.60 (0.95)	1.67	6.00	4.18 (1.10)
Girls	1.00	5.75	2.69 (1.00)	1.00	6.00	4.43 (1.14)
Total	1.00	6.00	2.65 (0.98)	1.00	6.00	4.31 (1.13)

(low, intermediate, and high). No significant differences between the three statement conditions were found for girls, $\chi^2(4) = 2.50$, $p = .65$, but for boys, a significant difference was found, $\chi^2(4) = 10.01$, $p = .04$. However, this difference disappeared after the FDR correction.

Finally, we conducted a multinomial logistic regression to analyze whether participants' agreement with the statements influenced their CRT score, separately for boys and girls and for participants who received positive and negative statements. For the negative statements, no differences were found in CRT scores among boys (n = 56), $\chi^2(2) = 1.17$, $p = .56$, and girls (n = 64), $\chi^2(2) = 0.58$, $p = .75$. For the positive statements, no differences were found in CRT scores among girls (n = 61), $\chi^2(2) = 5.09$, $p = .08$. However, among boys (n = 59), differences in CRT scores were found, $\chi^2(2) = 7.59$, $p = .02$. Post hoc analyses revealed that boys who agreed more with the positive statements were more likely to have a low CRT score compared with a high CRT score, OR(95%) = .01–.81, $p = .03$. However, this effect did not survive the FDR correction.

Effect of Priming on Responses to Failure

Descriptive statistics of the response-to-failure task can be found in Table 9. Seventeen participants had one or more missing responses for one or both subscales of the response-to-failure task and were therefore excluded from the analyses (n = 346). Furthermore, four outliers were found for HA scores, indicated by z values larger than 2.58 or smaller than −2.58. Therefore, we conducted all analyses with and without outliers. No differences were found, and therefore only the analyses including outliers are reported here.

To analyze whether task performance was influenced by priming condition, a MANOVA with a 2 (Response-to-failure subscales: HA and PS) × 3 (Priming condition: positive, negative, and neutral) model was conducted. Using Pillai's trace, no effect of Priming condition on Response to failure was found, $V = .01$, $F(4, 686) = 1.10$, $p = .35$, observed power = .35.

Finally, we examined whether responses to the statements (mean agreement scores) influenced the response-to-failure strategies. We used two separate regression analyses for participants who received positively framed statements (n = 117) and for participants who received negatively framed statements (n = 113). Participants who received negatively framed statements did not differ in their responses on both subscales (see Table 10). However, an effect was found when participants received positive statements: When participants disagreed more with the positive statements, the scores of the subscale

Table 10. Linear Model of Priming Effect on Response to Failure, Divided into Helpless Attributions and Positive Strategies, Corrected for Multiple Comparisons (FDR)

	Helpless Attributions				*Positive Strategies*			
	b	*SE b*	*β*	*p*	*b*	*SE b*	*β*	*p*
Negative priming condition (n = 113)								
Constant	1.95	.38		**<.001**	4.16	.48		**<.001**
Mean score	0.20	.13	.14	.13	0.06	.17	.04	.71
Positive priming condition (n = 117)								
Constant	1.28	.55		**.02**	6.03	.60		**<.001**
Mean score	0.52	.19	.24	**<.01**	−0.64	.21	−.27	**<.01**

For the negative priming condition, $R^2 = .02$ for HA and $R^2 < .01$ for PS; for the positive priming condition, $R^2 = .06$ for HA and $R^2 = .07$ for PS.

Significant models after FDR correction for multiple comparisons (with an α level = .05) are shown in bold.

HA were higher, and when participants agreed more with these statements, the scores of the PS subscale were higher (Table 10).

Supplemental Study

Part 1

Analyses showed that most adolescents rated two of the three types of behavior as at least partly due to the still developing brain, as the confidence interval and mean score were higher than 3.0 within a 1.0–5.0 range: rebellious or disobedient behavior: $M = 3.22$, $SD = 0.81$, 95% CI [3.12, 3.32]; stubborn: $M = 3.32$, $SD = 0.90$, 95% CI [3.21, 3.43]. Most adolescents rated the stereotypical behavior "eager to learn" as neutral: $M = 3.00$, $SD = 1.07$, 95% CI [2.86, 3.13].

Part 2

Independent *t* tests were conducted to compare the value ratings between the negative and positive statements.

Table 11. Independent *t* Tests of the Difference between Positive and Negative Statements

Positive Statements	*Negative Statements*	M_{pos}	M_{neg}	*t*	*df*	*p*	*95% CI*
1. Due to **hormonal changes**, adolescents often experience intense emotions that influence their behavior.	1. Due to **hormonal changes**, adolescents often have intense emotions that they find difficult to properly control.	2.86	2.90	0.29	240	.78	−0.21, 0.28
2. Adolescents are good at **planning** and thinking flexibly because their brain is still developing.	2. Because their brains are still in development, many adolescents struggle to **plan** their activities.	2.63	3.02	2.67	238	*<.01*	0.10, 0.68
3. Adolescents are better at **adjusting their behavior** within a group than adults because they are more sensitive to social influences.	3. Adolescents are worse at **adjusting their behavior** within a group than adults because they are more sensitive to social influences.	2.73	3.41	4.74	234	*<.01*	0.40, 0.97
4. Adolescents often seek new and exciting experiences due to the continued **development of the emotional regions** in the brain.	4. Adolescents often display irresponsible and risky behaviors because their **emotional brain areas are still developing**.	2.31	3.00	5.55	237	*<.01*	0.44, 0.93
5. Adolescents are good at **ignoring irrelevant information** and are therefore less quickly distracted than adults.	5. Adolescents are not very good at **ignoring irrelevant information** and are therefore more easily distracted than adults.	2.77	3.04	1.66	233	<.10	−0.05, 0.59
6. Because adolescents increasingly gain **control over their behavior**, they are more frequently able to make well-thought-out choices.	6. Because adolescents have less **control over their behavior** than adults, they often make impulsive choices.	2.28	2.97	5.11	233	*<.01*	0.43, 0.97
7. During adolescence, **connections in the brain** become increasingly efficient, facilitating more complex thought processes.	7. During adolescence, **connections and networks in the brain** are not yet efficient, which makes complex thought processes difficult.	2.45	3.13	5.05	234	*<.01*	0.41, 0.94
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 behavior.	8. **Adolescents' brains** are less **flexible** than those of adults. As a result, they are less able to **learn from their mistakes** and adjust their behavior.	2.29	3.31	7.23	232	*<.01*	0.74, 1.30
9. **Your ability to learn** can change. As an adolescent, you can influence this by doing your best.	9. **Adolescents' ability to learn** is fixed. You have little influence on this, no matter how hard you try.	2.45	2.82	2.63	232	*<.01*	0.09, 0.65

Core concepts, overlapping between the positive/negative versions, are displayed in bold.

Significant models after FDR correction for multiple comparisons (with an α level = .05) are shown in italic.

The independent t tests revealed that most statements were significantly differently valued between the positive and negative versions by the participants, with negatively framed statements being valued more negatively. However, for Statements 1 (hormonal changes) and 5 (dealing with irrelevant information), no statistically significant difference was found ($ps < .78$; see Table 11 for an overview).

As no significant differences in value ratings were found between the positively and negatively framed versions of Statements 1 and 5, we analyzed the data from the original study to examine how agreement on the statements was related to performance on the tasks when excluding Statements 1 and 5. The analyses examining the effect of agreement with the statements on risk-taking behavior (BART scores) showed similar results with (negative statements: $b = 7.87$ [2.73, 13.02], $p < .01$; positive statements: all regression models, $p = ns$) and without Statements 1 and 5 (negative condition: $b = 6.77$ [1.95, 11.58], $p < .01$; positive condition: all regression models, $p = ns$).

The analyses examining the effect of agreement with the statements on impulsivity (CRT scores) showed similar results with and without Statements 1 and 5 when participants received negative statements (no differences among boys: $n = 56$, $\chi^2(2) = 2.55$, $p = .28$, and girls: $n = 64$, $\chi^2(2) = 1.18$, $p = .55$) as well as when boys received positive statements (with Statements 1 and 5: $n = 59$, $\chi^2(2) = 7.59$, $p = .02$; without Statements 1 and 5: $n = 59$, $\chi^2(2) = 8.00$, $p = .02$). However, when girls received positive statements, differences in CRT scores were found when excluding Statements 1 and 5 ($n = 61$), $\chi^2(2) = 6.52$, $p = .04$, whereas this effect was not found when Statements 1 and 5 were included in the analyses. Post hoc analyses revealed that girls were more likely to have a low CRT score compared with an intermediate CRT score when they agreed more with the positively framed statements. However, this effect did not survive FDR correction. So, considering these corrected statistics, also in this analysis, the results were similar when Statements 1 and 5 were excluded.

Finally, the analyses examining the effect of agreement with the statements on response to failure also showed similar results with and without Statements 1 and 5 (see Table 12).

Part 3

Analysis revealed that most participants thought that the described behaviors used in the priming statements were more common during adolescence compared with childhood ($M = 2.74$, $SD = 0.55$, 95% CI [2.67, 2.81], range = 1.00–3.00; see also Figure 3). This indicates that

Table 12. Linear Model of Priming Effect on Response to Failure, Divided into HA and PS, Corrected for Multiple Comparisons (FDR), with and without Statements 1 and 5

	Helpless Attributions				*Positive Strategies*			
	b	*SE b*	*β*	*p*	*b*	*SE b*	*β*	*p*
With Statements 1 and 5								
Negative statements ($n = 113$)								
Constant	1.95	.38		**<.001**	4.16	.48		**<.001**
Mean score	0.20	.13	.14	.13	0.06	.17	.04	.71
Positive statements ($n = 117$)								
Constant	1.28	.55		**.02**	6.03	.60		**<.001**
Mean score	0.52	.19	.24	**<.01**	−0.64	.21	−.27	**<.01**
Without Statements 1 and 5								
Negative statements ($n = 113$)								
Constant	1.90	.34		**<.001**	4.48	.44		**<.001**
Mean score	0.23	.12	.17	.07	−0.06	.16	−.03	.73
Positive statements ($n = 117$)								
Constant	1.25	.47		**<.01**	5.87	.51		**<.001**
Mean score	0.55	.17	.29	**.001**	−0.60	.19	−.29	**<.01**

Significant models after FDR correction for multiple comparisons (with an α level = .05) are shown in bold.

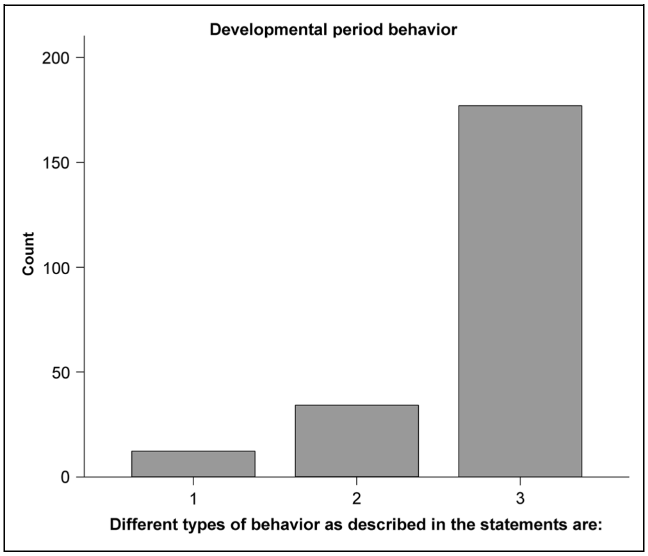

Figure 3. Adolescents' choice (one of three options) of the developmental period they thought that the described behaviors in the priming statements are most common. The different types of behavior as described in the priming statements are (1) more common during childhood compared with adolescence, (2) equally common during childhood and adolescence, or (3) more common during adolescence compared with childhood.

our study findings are specific to adolescence compared with childhood.

DISCUSSION

The aim of this study was to better understand how neuroscience impacts the real world. By asking both adolescents and parents about their associations with the word "teenage brain," we examined views on this neuroscience-based topic in the real world. Furthermore, the effect of priming with positively or negatively framed statements about adolescent neurocognitive development on adolescent behavior was examined. The results confirmed the idea that undesirable behaviors are more often mentioned when thinking about the teenage brain and, in addition, that adolescents were more likely to behave in line with their ideas about adolescent neurocognitive development in risk-taking behavior and in their response to academic failure. We discuss each of these findings and their implications in more detail below.

Perspectives on the Teenage Brain

Perspectives on the teenage brain were examined through free associations of both adolescents and parents and by analyzing adolescents' agreement toward positively and negatively framed statements. Associations revealed that, although parents frequently mentioned the developmental aspects of the teenage brain (e.g., "growing"), their associations were dominated by negative conceptions of the adolescent brain. Interestingly, this was also reflected in the adolescents' responses, who expected that adults (such as their parents or teachers) would report that the teenage brain causes mostly undesirable behaviors (e.g., "irritating"). When asked about their own conceptions, adolescents mentioned negative conceptions more often, but to a lesser extent than parents. However, their opinions regarding the scientific statements revealed that they were more likely to agree with statements about positive compared with negative consequences of adolescent development. This suggests that they may also be open to the positive connotations of continued neurocognitive development.

Combining these results, we could argue that adolescents themselves think that the teenage brain is something positive and creates opportunities, whereas parents associate the teenage brain especially with difficulties and undesirable behaviors. However, parents also view adolescence as a unique developmental transition characterized by possibilities, rather than a static and unfortunate developmental stage. Parents' perceptions are in line with the lay message about the teenage brain, which often emphasizes negative aspects of adolescence and warns caregivers of the consequences (van de Werff, 2017; Choudhury et al., 2012). These perceptions may result from unbalanced (and incorrect) translations of scientific work, for example, through endorsement of misconceptions about the brain (van de Werff, 2017; van Atteveldt et al., 2014; Dekker et al., 2012). The aspects of adolescence discussed in the scientific literature are more nuanced and even characterize adolescence as a unique period with many advantages, such as adapting quickly to a new environment (Sercombe, 2014; Crone & Dahl, 2012). Despite the more nuanced aspects of adolescent neurocognitive development, lay people may receive predominantly negative information through media reporting and therefore associate adolescence and the teenage brain with the occurrence of undesirable behaviors.

Our findings complement previous literature on neuroscientific lay messages, in which they elaborated on the negative aspects of the neurocognitive development of adolescence (van de Werff, 2017; Choudhury et al., 2012), by differentiating between caregivers and adolescents' perspectives on the teenage brain, including their perceptions of each other's perspectives. Interestingly, adolescents think that adults generally have negative conceptions about the teenage brain, suggesting that they are also aware of the more negative lay message as reported in the popular media. By contrast, although adolescents also gave predominantly negative associations, their higher agreement with positive versus negative statements shows that they are also concerned with the positive consequences of the teenage brain. Previous literature suggests that expectations of adolescent behavior are predictive of the later occurrence of this behavior (Buchanan & Hughes, 2009), suggesting that parents' expectation of undesired behaviors may influence adolescents' actual behaviors. The contribution of adolescents' own beliefs about neuroscience to their behavior is discussed in more detail below.

Effect of Priming on Risk-taking, Impulsivity, and Response to Failure

Differences in risk-taking behavior, impulsivity, and response to failure in adolescents after priming were examined by comparing the different priming conditions. First, the absence of general priming effects on all three of these typical adolescent behaviors indicated that the primed perspectives on the teenage brain had no direct influence on adolescents' behaviors. Our findings from the supplemental study suggest that most adolescents thought of rebellious or disobedient behavior and stubborn behavior being at least partly the result of the still developing brain. However, adolescents have a less pronounced opinion that eagerness to learn is the result of the still developing brain. This may be the result of media reporting in which brain development is used to explain stereotypical behaviors during adolescence, emphasizing more often on negative behaviors such as rebellious and stubborn behaviors and omitting the effect of brain development on more positive behaviors such as eagerness to learn (van de Werff, 2017). Furthermore, in the supplemental study, the positive priming statements were more positively rated compared with the negative priming statements, which were more often rated as neutral (see Table 11). This may suggest that adolescents might not think that possible negative consequences of adolescence are actually negative. Possibly, they compare the described behaviors with peers who show that particular behavior and feel that it is not a negative behavior. Finally, the supplemental study suggests that the described behaviors were specific behaviors during adolescence (vs. childhood; see Figure 3). These findings make it unlikely that the absence of priming effects may have been the consequence of the statements not being different enough in value (positive vs. negative) or not being specific enough to adolescence to prime adolescents on the negative versus positive stereotypes of the teenage brain. It seems more likely that adolescents' perspectives on the teenage brain build up over time and are not influenced by a one-time instance of processing positively or negatively framed information. This is in line with science communication research showing that people tend to believe scientific information in such a way that it fits their preexisting knowledge or worldview (e.g., O'Connor & Joffe, 2013). In line with these studies, we did find more nuanced effects of answering the framed statements on behavior: (a) Agreeing more with negatively framed statements about the teenage brain predicted more risk-taking behaviors, and (b) agreeing more with the positively framed statements predicted the use of more positive strategies after an academic setback, whereas (c) disagreeing more with the positively framed statements predicted the use of more helpless attributions after an academic setback. These results corroborate the suggested effect of already held beliefs about the developing adolescent brain and suggest that adolescents' beliefs interact with reading new information in a reinforcing manner, as agreement with negatively framed statements only predicted risk-taking behavior, agreement with positively framed statements only predicted an adaptive response to failure, and disagreement with positively framed statements only predicted nonadaptive responses to failure.

In summary, the adolescents' view of adolescent neurocognitive development affected their behavior in complementary ways. First, adolescents who agreed more with negative statements about adolescent brain development showed increased risk-taking behaviors. This finding is consistent with earlier findings of Buchanan and Hughes (2009), who reported that adolescents show more risk-taking and rebellious behaviors when, 1 year earlier, both the adolescents and their mothers expected that the adolescents would show these behaviors. This study and other previous studies suggest that expectations of behavior can result in biases toward the expected behavior (Qu et al., 2016; Buchanan & Hughes, 2009). This suggests that both expectations and actual behavior can be shaped by behaviors that are considered normative (Qu et al., 2016).The findings of our study complement these previous studies by showing that adolescents' negative beliefs regarding adolescent brain development lead to increased risk-taking behaviors in an experimental task instead of self-reported risk-taking behaviors. However, it has been argued that risk-taking is not maladaptive in situations where the benefits of taking the risk outweigh the costs (Ellis et al., 2012), and therefore more risk-taking behavior is not necessarily a bad thing. Risk-taking can also be beneficial to adolescents by allowing them to quickly adapt to new environments, thereby meeting more people and possible partners and learning about who they are (Sercombe, 2014). It is important that these positive effects of risk-taking are communicated in media reporting as well to create more balanced perspectives of the teenage brain.

Second, adolescents who agreed more with positive statements about adolescent brain development were more likely to use positive strategies to cope with failure. In addition, adolescents who disagreed more with the positive consequences of this development were more likely to use helpless attributions in response to academic failure. This finding is consistent with earlier findings of the impact of beliefs about learning and intelligence on response to failure (Blackwell et al., 2007). These findings show that even more general beliefs about the flexible, sensitive, and changing adolescent brain seem to relate to more adaptive responding to setbacks.

Surprisingly, adolescents' agreement with either negative or positive statements had no effect on adolescents' cognitive impulsivity. One possibility could be that, as the adolescents in our study are still attending school, they are more frequently exposed to the type of questions used in the CRT than the previously studied older populations. This "training" may cause them to be less impulsive when faced with the task. However, the scores on the questionnaire were similar to the scores in the original article (Frederick, 2005), suggesting that our participants did not perform differently to older groups. Another possibility could be that beliefs about the development of the teenage brain do not influence cognitive impulsive behaviors. This would be contrary to previous literature suggesting that social contexts strongly influence the development of decision-making processes, including impulsivity (Crone & Dahl, 2012). Therefore, further research is needed to examine the effect of beliefs about the development of the adolescent brain on impulsive behavior in cognitive contexts during adolescence.

We can conclude that the framing of neuroscientific information matters, although a one-time instance of exposure to information may not have consequences in and of itself. Our findings suggest that adolescents' views of their developing brain impact their behavior. In addition, their parents' perspectives about the teenage brain, such as "impulsive behavior" or "not able to plan activities," may act as self-fulfilling prophecies and influence adolescent behavior (Buchanan & Hughes, 2009). Other environmental influences such as societal belief in stereotypes (Qu, Pomerantz, McCormick, & Telzer, 2018) and cultural differences (Qu et al., 2016) also seem to influence adolescent behavior. These combined influences determine how adolescents view themselves, and this assessment seems to be driven in part by their understanding of the developmental (neuro)science research. Consequently, our findings suggest important implications for scientists in communicating their study results guaranteeing beneficial buildup of a realistic, and not only negative, understanding of the developing adolescent brain. More importantly, it has been shown that the framing or even misrepresentation of results in abstracts and conclusions in scientific articles is often adopted in press releases and media reports (Yavchitz et al., 2012; Gonon, Bezard, & Boraud, 2011) and is also used to give parenting advice (van de Werff, 2017). Therefore, scientists need to be proactive in framing their research findings in a balanced and realistic way and need to think about how their research will be received by and impact the real world. An adaptive view of adolescent development will create a more realistic belief of neuroscience in press releases, media reports, and parenting manuals, and as a result, this adaptive view creates a better society as a whole (Sercombe, 2014).

Our study has some limitations and possible directions for future research that should be taken into account. First, in our coding process, we categorized the associations adolescents and parents made with the teenage brain, without consulting how they themselves felt that their association should be labeled, for example, whether "lazy" should be labeled as an "undesirable behavior." However, because societal norms determine what kind of behavior is considered desirable and what is not and because both raters are highly familiar with the Dutch society, these categories are likely to represent the relevant socially constructed behaviors. Still, future studies could consider to let people categorize their own associations to validate that the associations are correctly labeled. Furthermore, it would be interesting to study how often adolescents demonstrate their mentioned behavior and use these data to link adolescents' associations with the teenage brain to their own behavior. Second, we cannot be completely sure that the mentioned associations in our study are all linked to the teenage brain specifically, because we did not ask our participants whether they would relate their given associations to neuroscience. However, findings from our supplemental study suggest that most adolescents think that the associations are neuroscience specific. Furthermore, the Dutch word "*puberbrein*" is in essence a compound of "showing puberty-related behavior" and "brain," and it is therefore likely that all associations were linked to the teenage brain as a whole. It is important to note that our results may not completely generalize to other countries, because of the specific meaning of "*puberbrein*." Third, we tried to capture the most prevailing stereotypes of adolescent behavior with our priming statements. However, stereotypes about adolescents' sensitivity toward social stimuli, such as their interpretation of peer-related social cues (Haller et al., 2017), were not explicitly formulated in our statements. Future studies could consider including statements in which adolescent stereotypes toward social stimuli, such as succumbing to peer pressure or excessive comparison with peers, are used more explicitly.

Conclusion

Our results of free associations with the term "teenage brain" show that adolescents and parents' perspectives of the teenage brain are in line with the often unbalanced overviews of scientific research displayed in the media (van Atteveldt et al., 2014), which often emphasize negative behaviors (van de Werff, 2017). Interestingly, although we did not find general effects of priming adolescents with negatively versus positively framed neuroscientific information on their behavior, a more nuanced effect was found; information that supported adolescents' ideas about adolescent brain development reinforced subsequent behaviors. These results show how neuroscience knowledge affects public discourse and thereby highlights the importance of incorporating the perspective of parents and adolescents when determining how to responsibly move toward dissemination and potential implementation of neuroscience findings. In addition, communication about adolescent neurocognitive development should be framed in a more balanced way to prevent negative public perceptions of the teenage brain from becoming self-fulfilling prophesies. So, before we are fully ready for real-world neuroscience, we need to be much more aware of how our neuroscience research impacts the real world.

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Note

1. The "teenage brain" is a compound in Dutch ("*puberbrein*") in which the words "*puber*," which is derived from the verb "*puberen*" meaning "showing puberty-related behavior," and "*brein*" are densely intertwined. This word is frequently used and well known among the Dutch population.

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