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TITLE: When the Brain Cares: Personal interests amplify engagement of language, self-reference, and reward regions in the brains of children with and without autism

AUTHORS: Halie A. Olson*[†1,2], Kristina T. Johnson[†3,4], Shruti Nishith[1], Isabelle R. Frosch[5], John D.E. Gabrieli[1,2], Anila M. D'Mello*[6,7,8]

[1]McGovern Institute for Brain Research, Massachusetts Institute of Technology, [2]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, [3]Department of Electrical & Computer Engineering, Northeastern University, [4]Department of Communication Sciences & Disorders, Northeastern University, [5]Department of Psychology, Northwestern University, [6]Department of Psychiatry, University of Texas Southwestern Medical Center, [7]Peter O'Donnell Jr. Brain Institute, University of Texas Southwestern Medical Center, [8]Department of Psychology, University of Texas Dallas

[†]Authors share joint first authorship.

*Corresponding authors.

ABSTRACT

Human language is shaped by individual experiences and interests. However, to study language in the brain, researchers use generic stimuli, avoiding the variable personal interests that typically animate language. Thus, it is unknown how personal interests affect language function in the brain. We conducted personalized functional magnetic resonance imaging (fMRI) in 20 typically-developing children as they listened to personalized narratives about their specific interest and non-personalized, generic narratives. Personally-interesting narratives amplified engagement of language regions, producing more consistent activation patterns across individuals – even though each narrative was unique – than the generic narratives. The personalized narratives also engaged self-reference and reward areas of the brain associated with motivation. Amplification of brain responses to personally-interesting narratives was also observed in 15 autistic children, a condition characterized by both intense specific interests and difficulties with communication. Here we show that personal interests significantly affect language processing in the human brain.

INTRODUCTION

Human language is informed by personal experiences, backgrounds, intrinsic motivations, and, in particular, individual *interests*. However, when studying language processing in the laboratory, researchers typically use impersonal and generic stimuli to purposefully avoid great variation among humans in precisely those personal interests and motivations that animate language and communication (e.g., [1]). Remarkably, therefore, little or nothing is known about how personal interests modulate language processing in the human brain. This phenomenon is of particular interest in children who are learning about their worlds and rapidly developing both their individual interests and language skills. To begin addressing this gap in knowledge, we used functional magnetic resonance imaging (fMRI) to measure brain activation while children passively listened to stories that were personalized to their interests.

The concept of "interest" merges two often interlinked experiences: the immediate fascination one has with a subject or item, and the lasting impression that the subject is enjoyable and merits further investigation. Interests are marked by heightened focus, a sense of comfort, and a lasting inclination to revisit the subject repeatedly [2–4]. Importantly, interests are inherently personal and idiosyncratic, varying between individuals and spanning a wide range of topics. This makes it all the more special when people find others who share their interests, and, perhaps unsurprisingly, shared interests promote social engagement and generous behaviors in children [5].

Interests can also be powerful motivators of language comprehension and communication [6]. For instance, interesting materials are sometimes used to motivate learning and academic achievement [7,8]. Likewise, children who score poorly on tests of reading comprehension for generic material often score better when these tests involve interesting [9] or familiar [10] material.

Autism spectrum disorder (ASD), in particular, is associated with a high prevalence of intense specific or restricted interests that are sometimes seen as a hindrance for communication [11–15]. However, scaffolding communicative interactions and interventions around topics of personal interest can enhance broad communication skills in autism (e.g., [16–21]).

Despite the fundamental link between language and personal interest, little is known about how individual interests modulate language functions in the human brain. Notably, some prior neuroimaging studies have successfully used personalized stimuli when studying other phenomena – such as food cravings or memories [22,23]. These studies are based on the intuition that personalization (e.g., a favorite food or a video of a specific memory) might be the most effective and ecological way to elicit neural responses in brain regions that process those stimuli Similarly, a few studies investigating autistic individuals have employed topics of personal interest (in the form of static photos, gifs [24,25], and task reinforcers [26,27]) as well as other personalized stimuli (e.g., mother's face vs. unfamiliar face[28]). These studies have found higher activation to interesting or personalized stimuli even in reward and face processing regions that are commonly underactive in autism. Together these studies suggest that across domains, personally-relevant materials potentiate brain networks generally involved in processing a given cognitive domain.

For the first time, we used a personalized fMRI paradigm to examine how topics of interest modulate language function in the brain. We focused on children, a population that is especially sensitive to their own interests. We recruited children (n=20, 6.98-12.01 years) with highly specific interests to participate in an individually-tailored fMRI experiment during which they listened to personalized narratives written about their interests, as well as to non-personalized narratives about nature. The non-personalized narratives were the same across all

children. Based on the behavioral literature findings that interests can modulate language performance [6–9], and that personalization effectively localizes activation in stimulus-specific brain regions [22,23,25–28], we hypothesized that personally-interesting narratives would elicit higher activation than non-personalized, generic narratives within language regions. Furthermore, because interests are highly rewarding, we also hypothesized that personally-interesting narratives would elicit higher activation in reward-related regions important for motivation. Finally, we tested whether the hypothesized effects of personally-interesting narratives on the brain would extend to a group of n=15 children (8.18-13.27 years) with autism – a condition characterized by challenges in language and communication as well as the presence of strong specific interests [11–13]. In both groups, in addition to measuring the magnitude of responses across the brain, we also assessed functional connectivity profiles and the degree of inter-participant consistency in brain responses for personalized and non-personalized narratives.

RESULTS

Our sample included 20 children, each with a strong specific interest. There was substantial variation among topics of interest between children, ranging from soccer to Minecraft to musicals (see **Supplementary Table 1**). For each child, we wrote and recorded personalized narratives based on interview responses and materials provided by children and their family. All narratives were audio recorded by one female researcher. Children then came into the lab to participate in the neuroimaging study, during which we acquired fMRI data while they listened to short narratives in three conditions: INTEREST, NEUTRAL, and BACKWARDS (**Figure 1**). In the INTEREST condition, participants listened to personalized narratives based on a topic of high interest. In the NEUTRAL condition, participants listened to non-personalized narratives

describing nature scenes. Nature content included in the neutral narratives was similarly familiar to all children and unrelated to any child's personal interest. In the BACKWARDS condition, participants listened to reversed versions of the neutral narratives in order to account for lower-level auditory features of the narratives. Children were instructed to passively listen to the narratives and press an in-scanner button box when they saw an attention check on the screen. Attention check accuracy was high across all children (mean >96%). A series of single-subject and group-level neuroimaging analyses were conducted to determine how personally-interesting narratives modulate brain activation.

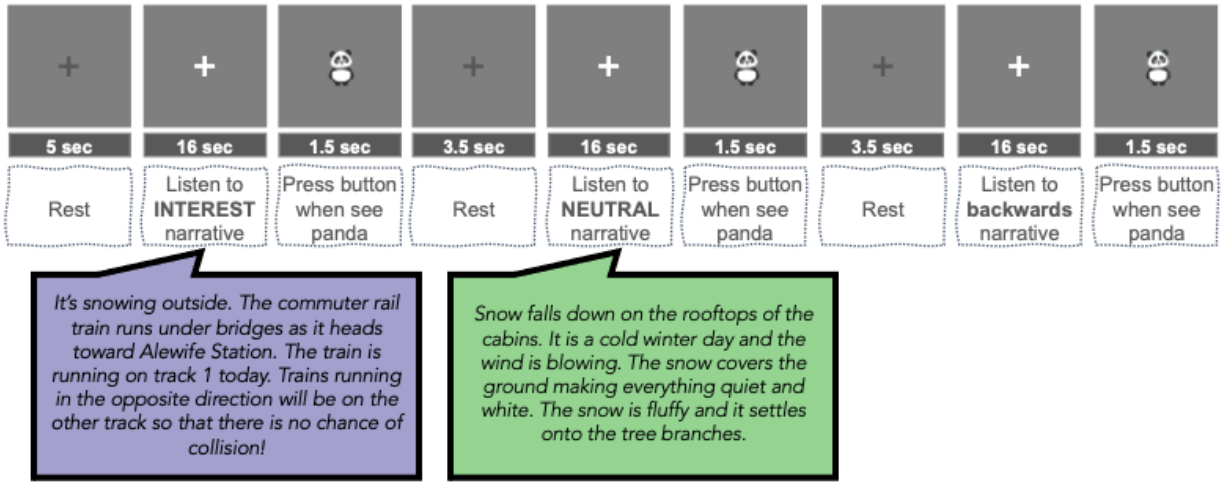

Figure 1: Task design. *Participants passively listened to 16-second narratives in three conditions (INTEREST, NEUTRAL, and BACKWARDS) in a fixed order. Each run contained 21 blocks (7 per condition).*

Personally-interesting narratives increase activation in language regions

First, to determine whether personally-interesting narratives modulate activation in regions canonically associated with language processing, we extracted functional responses from each task condition (INTEREST, NEUTRAL, BACKWARDS) from eight *a priori* left frontal,

temporal, parietal, and right cerebellar regions of interest (ROIs) [29]. A mixed-effects model determined that brain activation differed by condition ($F(2,451) = 121.43$, $p < 0.001$). As expected, comprehensible, generic narratives activated language regions more than incomprehensible, backwards narratives (NEUTRAL>BACKWARDS: $t(451) = 4.89$, $p < 0.001$). In addition, activation was higher for personally-interesting narratives than for both non-personalized (INTEREST>NEUTRAL: $t(451) = 10.37$, $p < 0.001$) and backwards ($t(451) = 15.26$, $p < 0.001$) narratives (**Figure 2A**). We also assessed whether listening to personally-interesting narratives impacted functional connectivity between language regions. Inter-region correlations among canonical language regions did not differ significantly for the INTEREST compared to the NEUTRAL condition (**Figure 2B**). This suggests that modulating interest did not impact how language regions interacted with each other.

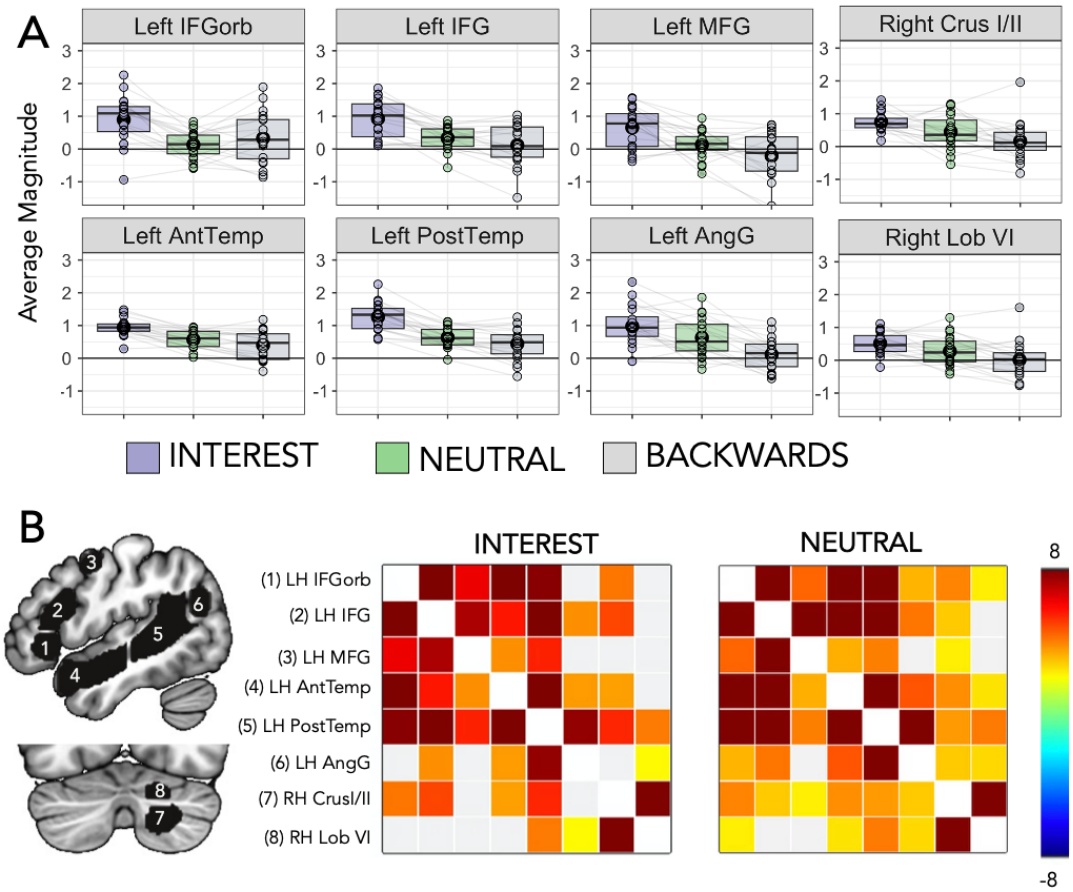

Figure 2: Response within a priori language regions of interest in neurotypical children. *(A) Boxplots show average magnitude per condition, per participant, in each a priori language region of interest. Circles represent individual participants; gray lines connect individual participants across conditions. Black circles represent the mean. (B) LEFT: A priori language regions of interest.* [30] *RIGHT: Functional connectivity between language ROIs for the INTEREST and NEUTRAL conditions.*

Unlike generic language stimuli, personally-interesting narratives feature topics that are highly motivating and familiar for each child. We therefore conducted unbiased, whole-brain analyses to examine whether personally-interesting narratives elicited higher activation than neutral narratives outside the regions typically engaged in processing generic language stimuli. In addition to canonical language regions (e.g., bilateral superior and middle temporal gyri, bilateral inferior frontal gyrus, and right cerebellum; as expected based on the ROI analyses),

personally-interesting narratives increased activation in regions associated with reward (e.g., caudate, nucleus accumbens, ventral tegmental area/substantia nigra) and self-referential processing (e.g., ventromedial and medial prefrontal cortex [vmPFC and mPFC], and precuneus/posterior cingulate) (**Figure 3A)**. Further, increased activation for personally-interesting narratives over non-personalized narratives was present both at the group level and at the level of individual children (**Figure 3B;** for individual responses in all participants, see **Supplementary Figure 1)**.

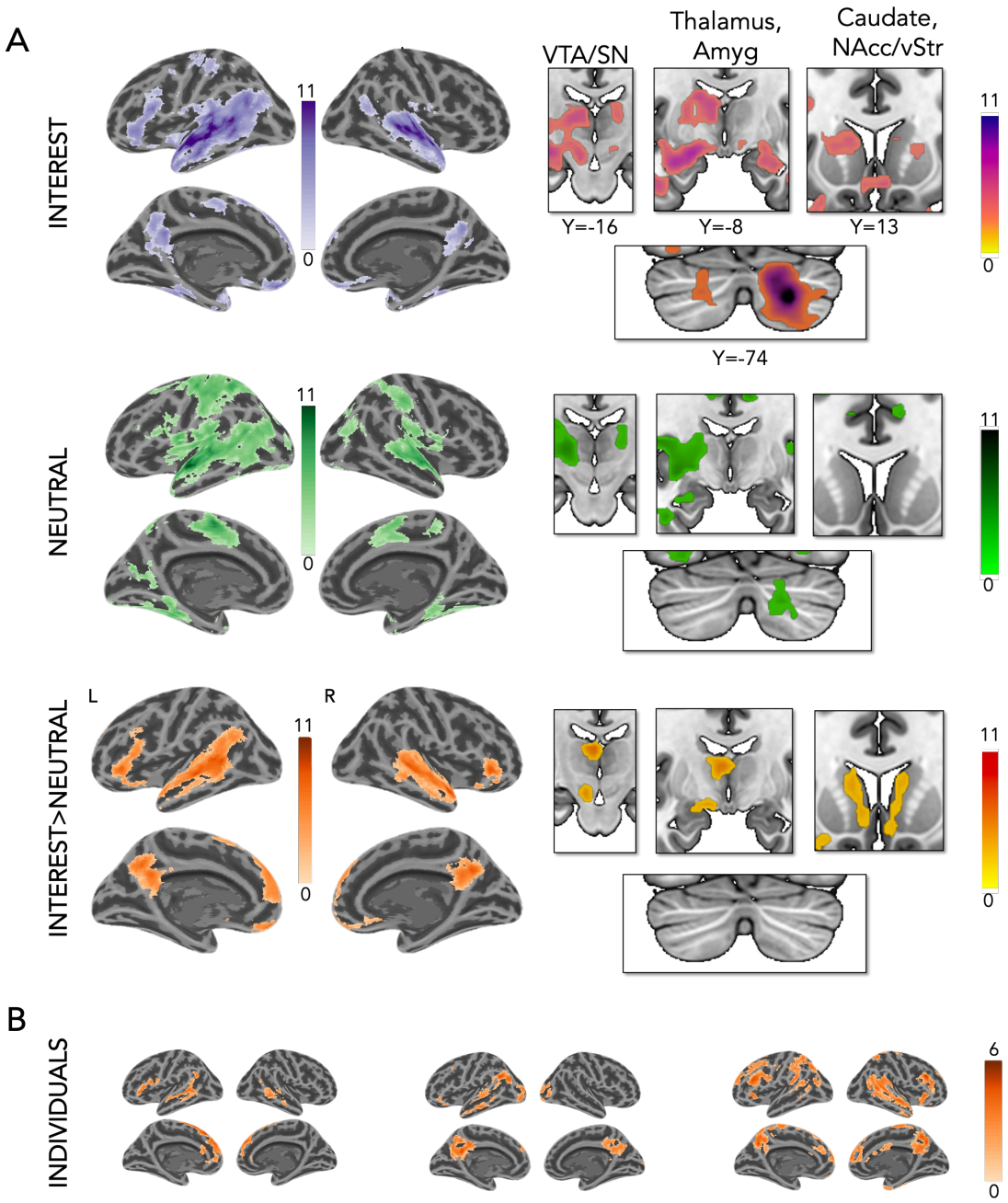

Figure 3: Whole-brain responses within neurotypical children. *(A) Whole-brain activation maps for the INTEREST, NEUTRAL, and INTEREST>NEUTRAL contrasts. Threshold: p<.001, FWE corrected at p<.05. (B) Individual whole-brain responses from three participants to INTEREST>NEUTRAL language visualized at p<.01, FWE cluster p<.05.*

Personalized narratives activate brains consistently despite idiosyncratic topics

A concern with personalization is that using different materials will give rise to discrepant patterns of activation across individuals. Intuitively, given that non-personalized narratives were the same across individuals, one might expect more consistent patterns of activation across participants when children listened to these "neutral" narratives. In both the INTEREST and NEUTRAL conditions, we calculated the proportion of participants showing significant activation ($p < 0.001$) at each voxel in the brain. We examined voxels in which at least 25% of participants showed significant activation (i.e., intersubject overlap). We found that a greater number of voxels showed intersubject overlap for INTEREST than NEUTRAL narratives (**Figure 4A**). Regions of greatest overlap across participants included the temporal cortex, a core language region. Given substantial individual variation in functional activation patterns, quantifying participant overlap at the voxel level may underestimate correspondence between individuals (i.e., individuals may all activate very similar regions albeit different voxels). We therefore used a data-driven approach to identify and create functionally-defined parcels wherein at least 80% of subjects showed significant activation [29,31]. A greater number of parcels were identified for INTEREST than NEUTRAL narratives (**Figure 4B)**. These results suggest that even though stimuli were idiosyncratic, ranging in topic from train lines to video games, activation patterns for personally-interesting narratives were *more consistent* across participants than activation patterns for neutral narratives.

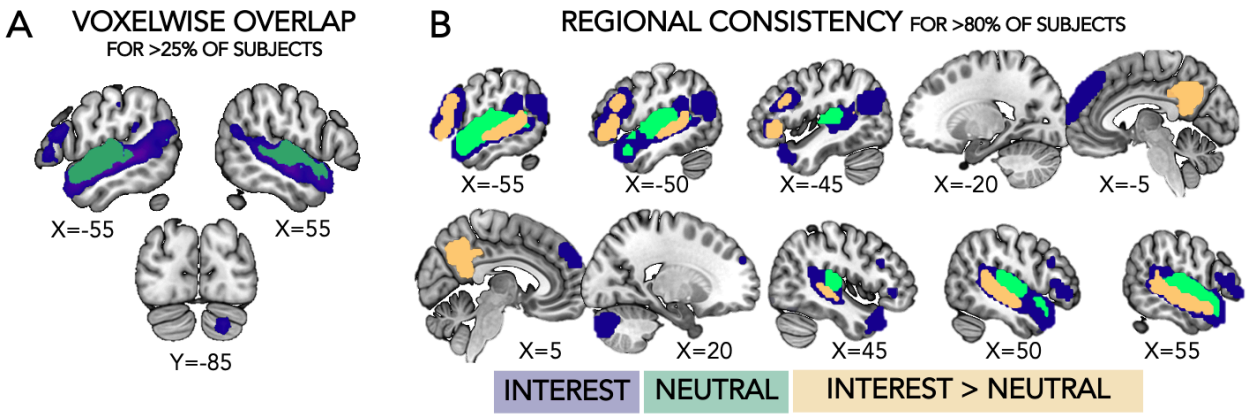

Figure 4: Consistency in individual responses amongst neurotypical children. *(A) Overlay of probability maps for INTEREST (purple) and NEUTRAL (green), each thresholded for 25% overlap at voxel level. (B) Parcels within which >80% of participants show significant activation for INTEREST (purple), NEUTRAL (green), and INTEREST>NEUTRAL (orange).*

Personally-interesting narratives increase brain activation in autistic children

Finally, we investigated whether the potentiating effects of personally-interesting narratives generalized to autism, a neurodevelopmental condition characterized by language challenges and a high prevalence of specific interests [12]. We scanned 15 autistic children with specific interests who were matched with the neurotypical (NT) group on nonverbal cognitive reasoning, and had lower scores on verbal comprehension and communication (**Supplementary Table 2**).

In the ASD group, a mixed-effects model determined that brain activation differed by condition ($F(2,336) = 47.71$, $p < 0.001$). Interestingly, unlike in the NT group, the ASD group showed no difference in activation between the NEUTRAL and BACKWARDS conditions in language regions (NEUTRAL>BACKWARDS: $t(336) = 1.17$, $p = 0.47$). However, like in the NT group, personally-interesting narratives elicited higher activation than neutral and backwards narratives in language ROIs (INTEREST>NEUTRAL: $t(336) = 7.81$, $p < 0.001$; INTEREST>BACKWARDS: $t(336) = 8.98$, $p < 0.001$; **Figure 5A**). As in NT children, functional connections between language regions were not altered by condition (**Figure 5B)**.

Whole-brain analyses also identified higher responses to INTEREST than NEUTRAL conditions in bilateral temporal regions and regions involved in reward (e.g., VTA) and self-referential processing (e.g., precuneus) (**Figure 5C**). These results were observable both at the group level and in individual participants (**Figure 5D;** for individual responses in all participants, see **Supplementary Figure 2**). Furthermore, as in NT children, autistic children showed more consistent activation patterns for personally-interesting over neutral narratives (**Figure 6**).

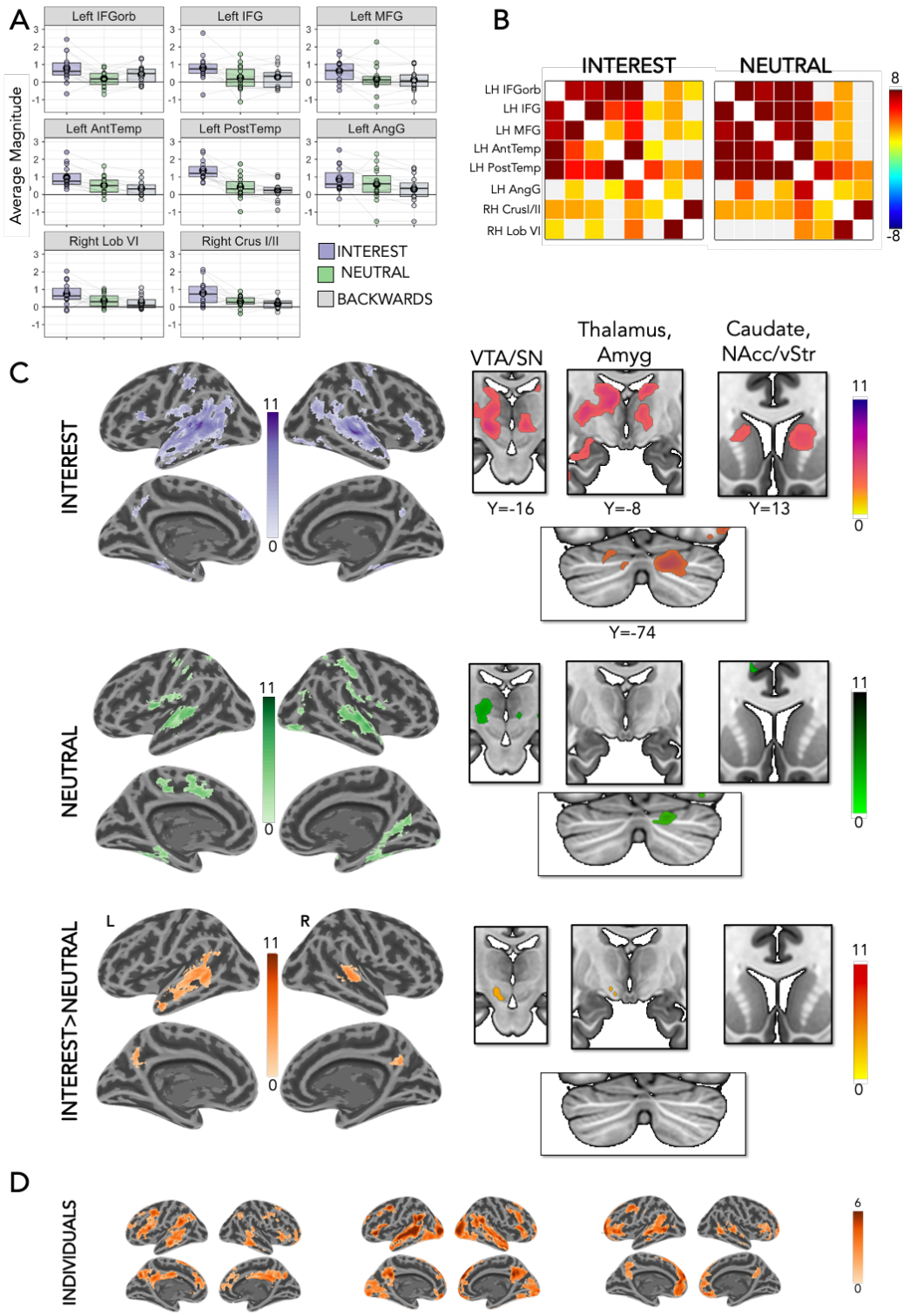

Figure 5: Response within a priori language regions of interest and across the whole brain in autistic children. *(A) Boxplots show average magnitude per condition, per participant, in each a priori language region of interest. Individual participants are connected by light gray lines.*

Black circles represent the mean. (B) Functional connectivity between language ROIs for the INTEREST and NEUTRAL conditions. (C) Whole-brain activation maps for the INTEREST>NEUTRAL contrast, as well as INTEREST and NEUTRAL relative to baseline fixation. Threshold: p<.001, FWE corrected at p<.05. (D) Individual whole-brain responses from three participants to INTEREST>NEUTRAL language visualized at p<.01, few cluster p<.05.

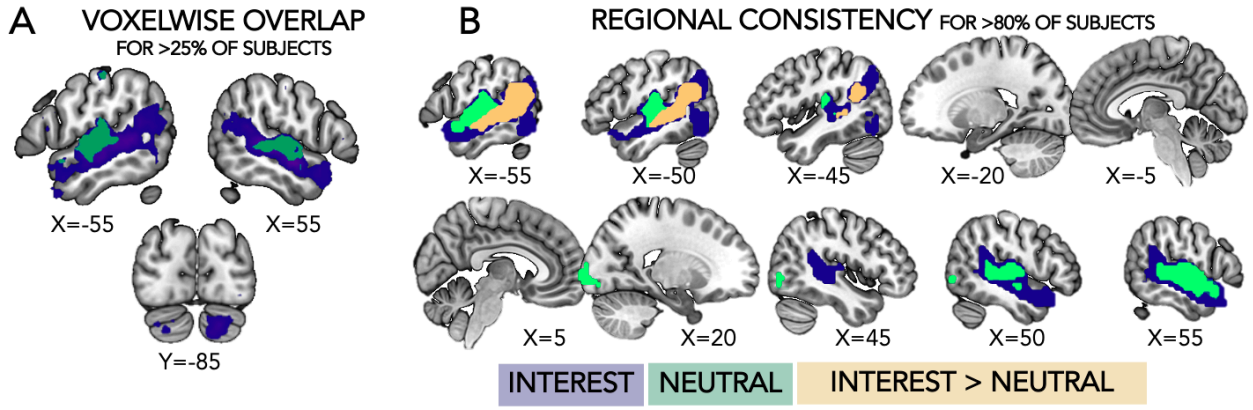

Figure 6: Consistency in individual responses amongst autistic children. *(A) Overlay of probability maps for INTEREST (purple) and NEUTRAL (green), each thresholded for 25% overlap at voxel level. (B) Parcels within which >80% of participants show significant activation for INTEREST (purple), NEUTRAL (green), and INTEREST>NEUTRAL (orange).*

Lastly, we conducted mixed-effects models to determine whether we could detect differences between the ASD and NT groups in any task conditions. Across language ROIs, there was no significant interaction between group and task condition when including both NT and ASD groups in the same model. We also found no significant group differences across the whole brain ($p < 0.001$, FDR cluster $p < 0.05$).

DISCUSSION

This is the first evidence that personalized, interesting language engages language, reward, and self-reference regions of the human brain in children above levels that are typically seen with generic language stimuli. Personally-interesting narratives led to higher responses in canonical

language regions such as the inferior frontal gyrus and middle and superior temporal regions. Such narratives also increased responses in reward regions (amygdala, ventral tegmental areas, and ventral striatum/caudate), which is consistent with the interpretation that personally-interesting narratives were more rewarding or engaging than non-personalized, generic narratives. Additionally, personalized narratives increased activation in default-mode regions (medial prefrontal cortex and precuneus/posterior cingulate) associated with self-reference. Notably, personalized narratives elicited higher activation in both neurotypical and autistic children.

Activation in canonical language regions was amplified by interest

In the current study, personally-interesting narratives increased activation in several neocortical and cerebellar regions typically activated by generic language [32–34]. This difference emerged even though both conditions were high-level narratives and closely matched on low-level aspects of language. This suggests that high-level language regions are sensitive to interest. Although no prior research has examined interest, previous studies have shown that different features of language (e.g., how surprising or predictable, semantically-plausible, grammatical, or challenging a sentence is) can upregulate or downregulate activation in language regions (e.g., [34–37]), whereas other features of language do not modulate activation in these regions (e.g., [38]). Notably, interest – unlike these other features – is determined by the individual and is not an intrinsic feature of the stimuli. This suggests that the degree to which any language stimulus, whether generic or personalized, activates the brain may be influenced by how interesting an individual finds the content.

Importantly, we also found that the functional architecture of the language network was not affected by interest: connections between major hubs of the language network were the same regardless of whether children were listening to personally-interesting or generic narratives. Thus, within language regions specifically, interest modulates the magnitude of the response without changing how these regions communicate with each other.

Although we found a robust effect of personal interest in language regions, it is unclear what mechanism drives this effect. Higher interest in the stimuli may have been associated with increased attention and arousal, higher intrinsic motivation, and greater personal relevance and familiarity with the topic. Indeed, attention has been shown to modulate activation in language regions [35,39], and can expand the tuning of voxels towards the attended semantic category during movie watching [40]. While children paid attention in both conditions in our study (i.e., responded equally in both conditions to the low-level attention checks), they were likely more engaged by, and may have paid more attention to, the personally-interesting narratives. In this vein, it is also possible that the neutral narratives may have elicited *lower-than-expected* activation due to the context of the task, in which those narratives were interleaved with highly salient, personally-interesting narratives.

Activation in reward and self-reference regions was also amplified by interest

Contrasting personally-interesting narratives with neutral narratives also resulted in increased activation in regions not typically associated with language. This included regions canonically associated with reward and salience, such as the amygdala, ventral tegmental area, and ventral striatum/caudate. We also found increased engagement of default-mode network (DMN) regions associated with self-reference, including the mPFC and precuneus/posterior cingulate, for

personally-interesting narratives. Increased activation in these regions may reflect the highly rewarding, salient, and familiar nature of personal interests to the individual. Prior studies, for instance, have found that activation in mPFC in precuneus/posterior cingulate is related to how personally relevant the material is [41,42]. These activation patterns may also reflect the fact that interests are closely linked to the self – both how individuals view themselves and the way they project to the world [2,3].

In typical language experiments, although not explicitly examined or controlled for, individuals may feel more or less interested in, excited by, or familiar with the linguistic stimuli. Indeed, studies of language that use more naturalistic stimuli – such as narratives rather than sentences – also find activation in the default mode network and basal ganglia [43–45]. Activation in these networks has similarly been noted in more controlled studies that experimentally manipulate reward and salience in language stimuli. Studies comparing mothers' voices to unfamiliar voices found engagement of reward, salience, and self-reference regions (e.g., nucleus accumbens, mPFC, precuneus) alongside canonical speech processing regions (e.g., bilateral superior temporal gyrus) in children [46,47]. In addition, manipulating children's beliefs about whether they were listening to a live person speaking versus a recording resulted in increased engagement of mPFC and precuneus [48]. Lastly, it is also possible that interesting narratives used in the current study brought online regions that typical neuroimaging paradigms using generic language stimuli are underpowered to detect. For example, in a large study of over 800 individuals, contrasting sentences versus non-words revealed activation of the mPFC, precuneus, left caudate, and hippocampus [30].

Considering personal interests when imaging the language system in autism

Almost 90% of school-age autistic children have been found to have a “special” or “circumscribed” interest [11]. Although typically characterized as interfering in daily life, these highly focused interests have also been described as rewarding and socially motivating by autistic individuals [49]. Moreover, clinical studies have also found that incorporating personal interests into interventions increases intervention efficacy and stimulates social communication in autistic children [16–19] – a finding which has also been highlighted by single cases [21]. In the current study, personally-interesting narratives led to higher activation in canonical language regions. These results are particularly compelling because autistic individuals often show difficulties in communication, and neuroimaging studies in autism have found atypical or reduced language responses [50–55]. Consistent with this, in our autism sample, we failed to find the expected difference between comprehensible and incomprehensible language when comparing generic versus backwards narratives in canonical language regions. On its own, this result might lead to the interpretation that language regions had a lower sensitivity to language in autism. However, when comparing personally-interesting narratives to generic narratives or backwards speech, these language regions were highly engaged. These findings suggest that interest may be more effective at capturing the capacity of language regions than non-interesting standard stimuli, particularly for autistic individuals who might differ in their engagement with or interpretation of the stimuli.

As in neurotypical children, listening to personally-interesting narratives was also associated with higher activation in reward, salience, and self-reference regions, such as the precuneus and ventral tegmental area. Although not in the domain of language, similar results have been found when using personal interests to probe the reward system in autism [26,27]. For instance, prior studies have found higher activation in bilateral caudate when using personalized

interests as a reward (in contrast to more canonical rewards such as social approval [26] or money [27]). In addition, viewing images of a strong personal interest was associated with increased activation in the amygdala [24], posterior cingulate [56], and fusiform gyrus [25] in autistic children.

Personalizing narratives to the individual reveals unexpected benefits

In addition to increasing activation across the brain in both NT and ASD children, personally-interesting narratives also resulted in *more consistent* patterns of brain activation across individuals than generic narratives. This is unexpected, as the personally-interesting narratives were idiosyncratic while generic narratives were the same across individuals. However, the goal of the current study was to drive participants' interest in the narratives to a ceiling. Therefore, although personally-interesting narratives differed in content, they may have been more similar than generic narratives in their ability to elicit attention, potentially resulting in more similar patterns of activation across individuals than generic narratives (wherein interest in the stimuli is arguably less controlled). While tight experimental control typically used in studies of language processing accounts for some low-level differences across participants, it may introduce confounds at other levels.

Similar to the idea that participants may vary in their level of interest in experimenter-designed stimuli, previous work has shown that researcher labels of stimuli do not always capture participants' subjective experiences of those stimuli, and that using participants' own reports rather than experimenter labels can explain more variance in brain activity [57]. Just as there is widespread awareness of (and analytical techniques to account for) individual differences in the functional organization of the human brain [29,58], these results suggest that there should be a

similar acknowledgement of individual differences in how participants subjectively experience experimental stimuli in neuroimaging studies.

A second benefit of personalized stimuli is that they may be more motivating for certain populations, such as very young children or those with neurodevelopmental and psychiatric conditions who have historically been challenging to study in the scanner. Utilizing interest to drive attention has been part of educational philosophy for at least a century – the idea being that if children are interested in a topic, they will engage with it more meaningfully and be motivated to try hard things [3,4,6]. Anecdotally, children in our study were very excited to go in the MRI scanner, specifically to watch videos and listen to stories about their interests. Using more naturalistic stimuli has been shown to improve data quality in pediatric samples [59–62]. Here, we suggest that interest may be an additional dimension and methodology that could increase engagement and thus, could more accurately capture the organization and function of the language network in these populations.

Limitations and Future Directions

This study was limited in a few ways that future work might aim to address, including limited statistical power, the fact that the inclusion criteria for the MRI study required an autistic group with low support needs, and the relative lack of task difficulty. In particular, the ASD group had a moderate sample size, resulting in reduced power to detect group differences. Future work should aim to replicate and extend these results, particularly with a larger and more representative sample of autistic children.

Second, because the personalized narrative stimuli were written about highly specific topics, there were some linguistic differences between the personalized and neutral narratives.

Although we controlled for a number of linguistic features between conditions, such as speaker and length of utterances (see **Methods** for additional details), by design, the personally-interesting narratives contained more specific vocabulary than the control narratives, including specific, correct terminology and proper nouns related to children's interests. In contrast, we avoided potentially unfamiliar vocabulary in the neutral narratives. However, these linguistic differences between conditions account for our results, as our effects were robust at the level of individual subjects despite variations in the degree of specific vocabulary (see **Supplementary Figures 1-2** and individual transcripts of the stimuli on OSF).

In this study, we did not test whether our results were driven by a *highly specific* interest per se, or rather by interest more generally. It is possible that the personally-interesting narratives might have been more engaging than the neutral narratives to anyone, regardless of whether the topic was actually a child's *specific* interest. How level of interest modulates language network activity is an exciting empirical question, and one that could potentially be addressed in future work by assessing level of interest to a wider variety of topics. It is worth noting, however, that this is not a trivial pursuit - figuring out how to measure levels of familiarity and interest across individual children may be complicated, and it is unclear what constitutes a "generally interesting" set of stimuli materials. Thus, although counterintuitive, personalizing based on a "top-choice" (e.g., favorite activity or interest) is an effective way to standardize the level of interest across participants. Regardless, a takeaway from this study is that content matters when it comes to language network activation.

Finally, the participants in this study were children, and therefore do not offer insight into whether interest would have as strong of an impact on language regions' activation in adults. Previous research suggests that other features of linguistic stimuli can drive and suppress

activation in adult language regions [35], and future research could investigate how impactful interest may be relative to these other features in an adult sample.

Conclusion

In sum, this study highlights how brain functions are altered by language inputs that align with individual interests, that these alterations influence language, reward, and self-reference neural systems, and that such an alteration is shared by both neurotypical and autistic children.

METHODS

Participants. Data were analyzed from 20 neurotypical children (ages 6.98-12.01 years, mean(SD)=9.35(1.52), 5 female/15 male) and 15 autistic children (ages 8.18 – 13.27 years, mean(SD)= 11.17(1.62), 3 female/11 male/1 nonbinary). All children were native speakers of English, had normal or corrected-to-normal hearing and vision, had no contraindications for MRI (e.g., metal in the body), and had a qualifying special interest (see **Personal Interest Screening** below). Additional exclusion criteria for the neurotypical children included diagnosis of major neurodevelopmental or psychiatric disorders and/or language difficulties. In n=9 autistic children scanned prior to the onset of the Covid-19 pandemic, autism diagnosis was confirmed via the Autism Diagnostic Observation Schedule (ADOS) administered by a research-reliable clinician [63]. A total of 54 children were originally recruited for participation (n=27 neurotypical, n=27 autistic), but n=19 were not included in these analyses due to refusal to participate in the fMRI scan or inability to stay in the scanner past the initial T1 (n=5), excessive motion for the language task (n=12), incidental findings (n=1), and incomplete data (n=1). One participant in the autism group returned post-pandemic since no usable functional data was collected on the

first attempt. Parents provided informed consent, and children provided assent to participate. This protocol was approved by the MIT Committee on the Use of Humans as Experimental Subjects.

Personal Interest Screening. Parents expressed interest in the study via an online screening survey. If a child was potentially eligible (i.e., appropriate age, no exclusions based on the criteria listed above, and parent-reported presence of a significant interest, hobby, passion, or affinity), a member of the research team conducted a phone screening and discussion with parents to (1) confirm eligibility, and (2) ask follow-up questions about the child's interest. Criteria for the presence of a personal interest were as follows: (1) the child must engage with the interest for at least an hour per day on average (or would engage with that interest for the specified amount of time if there were restrictions in place, such as screen time limits), (2) the child must have had the same interest for at least the last two weeks, and (3) the interest had to have associated videos that could be used in the fMRI experiment. Parents, in collaboration with their children, were then asked to provide video clips pertaining to their child's interest, which we used to create personalized stimuli for the fMRI experiment (see **Personalized Stimuli Creation**).

Experimental Protocol. Participants completed 1-2 study sessions, which involved behavioral testing and a neuroimaging session. The neuroimaging session included an anatomical scan, a functional run of a task involving watching the participants' selected interest videos and nature videos (not discussed in this paper), a functional run of the personal interest language task (see **Functional Personal Interest Narrative Task** for details below), and optional additional scans

that varied between participants. These options included a resting state scan, neural adaptation tasks involving faces, objects, and auditory words, a separate language task, a diffusion scan, and additional runs of the personal interest tasks. Parents completed a set of questionnaires about their child during the visit including questions with regards to demographic and developmental histories (e.g., language onset), the Autism Quotient (AQ [64]), and the Social Responsiveness Scale (SRS [65]).

Personalized Stimuli Creation. Parents, in collaboration with their child, provided links to online video clips (e.g., YouTube links) that captured their child's personal interest, including timestamps for their child's favorite parts of the videos. We cut seven 16-second clips from the provided videos (capturing each child's favorite part of the videos if provided), and wrote short narratives of the scenes from the selected video clips. A female experimenter (HAO) recorded the descriptions in a sound-proof booth, and the audio files were trimmed to be exactly 16 seconds. Language narratives were approximately matched between participants by avoiding personal pronouns, using simple vocabulary (allowing for interest-specific terms), and using short sentences. Due to the unique nature of the personal-interest video clips, the personal-interest narratives tended to have more specific nouns — e.g., "Alewife Station" or "Lionel Messi" — than the neutral narratives. Some, though not all, personally-interesting narratives also contained social content, such as discussions about specific people or human interactions; however, many personal interests across both NT and ASD groups were not social in nature (see **Tables 1-2**). Both the personally-interesting and neutral narratives included action verbs and sensorially evocative descriptions. See OSF (https://osf.io/dh3wq/) for the neutral and personally-interesting narrative transcripts for all children with usable data. Total word count,

number of words per sentence, number of syllables per word, and number of sentences per narrative were similar between neutral and personally-interesting conditions (Total word count: M(SD)=39.92(4.21) for personal-interesting across all participants and M=45.14 for the neutral narratives [same across all participants], Number of words per sentence: M(SD)=7.40(1.15) for personally-interesting and M=7.74 for neutral; Number of syllables per word: M(SD)=1.40(.10) for personally-interesting and M=1.23 for neutral, and Number of sentences: M(SD)=5.49(.83) for personally-interesting and M=6.0 for neutral).

Behavioral Measures. We conducted assessments of nonverbal reasoning and language skills to (1) ensure all children could understand task procedures and instructions, and (2) ensure there were no group differences in cognitive reasoning (i.e., IQ), and (3) characterize language skills in each group. Nonverbal cognitive reasoning was assessed via the matrices subtest of the Kaufman Brief Intelligence Test, 2nd edition (KBIT-2 [66]). Language skills were assessed via the verbal composite score of the KBIT-2, including the vocabulary and riddles subtests. See **Supplementary Tables 1-2** for details.

Functional Personal Interest Narrative Task. Participants were asked to passively listen to spoken narratives presented binaurally via MRI-compatible headphones using a block-design paradigm. The task consisted of three conditions: INTEREST, NEUTRAL, and BACKWARDS narratives. In the INTEREST condition, participants listened to the personalized narratives about their specific interests. In the NEUTRAL condition, participants listened to non-personalized narratives describing nature scenes. Nature content included in the neutral narratives were similarly familiar to all children and unrelated to any child's personal interest. In the

BACKWARDS condition, participants listened to incomprehensible reversed versions of the neutral narratives in order to account for lower-level auditory features of the narratives. Children listened to 7 narratives (16-seconds each) in each condition. Each narrative was followed by an inter-stimulus rest block of 5 seconds (total of 21 narratives across three conditions and 22 rest blocks). To confirm that children were attending to the task without imposing significant physical or cognitive demands, we included a low-demand attentional check following each narrative. An image of a panda appeared on the screen directly after each narrative for 1.5 seconds, followed by a blank screen for 0.5 seconds. Children were instructed at the beginning of the study to press a button using their pointer finger via an MRI-compatible button box that they held in their hand every time they saw a picture of a panda. Task order was fixed across participants in an [ABCABC…] pattern: INTEREST, NEUTRAL, then BACKWARDS. Total task time was 8min 8s.

Acquisition. Data were acquired from a 3-Tesla Siemens Prisma scanner located at the Athinoula A. Martinos Imaging Center at the McGovern Institute at MIT, using a 32-channel head coil. T1-weighted structural images were acquired in 196 interleaved slices with 1.0mm isotropic voxels (MPRAGE; TA=; TR=2530.0ms; FOV=256mm; GRAPPA parallel imaging, acceleration factor of 3). Functional data were acquired with a gradient-echo EPI sequence sensitive to Blood Oxygenation Level Dependent (BOLD) contrast in 3.0mm isotropic voxels in 40 near-axial slices covering the whole brain (EPI factor=70; TR=2500ms; TE=30ms; flip angle=90 degrees; FOV=210mm; TA=7:32).

Preprocessing and Statistical Modeling. fMRI data were preprocessed using fMRIPrep v1.1.1 [67], a pipeline developed by the Center for Reproducible Neuroscience. Preprocessing steps included motion correction, correction for signal inhomogeneity, skull-stripping, segmentation, co-registration, and spatial normalization to the Montreal Neurological Institute (MNI)-152 brain atlas. Preprocessed images were smoothed in SPM12 at 6mm FWHM. First level modeling was performed using SPM12. Individual regressors for each condition (INTEREST, NEUTRAL, BACKWARDS, and button press) were included in the model. Individual TRs were marked as outliers if they had greater than 1mm of framewise displacement. We included one regressor per outlier volume in the first level model, and we excluded participants with > 20% outlier volumes. The critical contrast (INTEREST > NEUTRAL) was created to examine regions showing greater activation for personally-interesting than neutral narratives.

Region of Interest Analyses. To determine whether personal interest activated language regions specifically, parameter estimates for each condition were extracted from *a priori* regions of interest (ROIs) known to be important for language processing [29]. These ROIs are based on an atlas comprised of functional data from 803 participants during language tasks and reflect regions wherein a high proportion of participants showed overlap in activation patterns [30]. From this atlas, we selected eight parcels that contain canonical language regions: left IFGorb, left IFG, left MFG, left AntTemp, left PostTemp, left AngG, right cerebellum lobule VI, and right cerebellum Crus I/II (**see below**). Linear mixed-effects models were run in R using the lme4 package. To determine if there was an effect of condition (INTEREST, NEUTRAL, BACKWARDS) across the "language network', we used:

$$Y_{BOLDfromROI} \sim X_{condition} + X_{(1|ROI)} + X_{(1|participant)}$$

with participant and ROI as random factors to account for repeated measures. Post-hoc tests were then conducted using the lsmeans package in R. To test for group by condition interactions, we also ran a model adding a group as a fixed effect.

Task-based Functional Connectivity Analysis. Task-based functional connectivity analyses were conducted using the CONN toolbox [68] as implemented in MATLAB to determine whether personal interest altered the functional architecture of the language network. ROIs consisted of language network ROIs from [30], as used for the univariate analysis (i.e., left IFGorb, left IFG, left MFG, left AntTemp, left PostTemp, left AngG, right cerebellum lobule VI, and right cerebellum Crus I/II). FMRI data were preprocessed (realigned, normalized, spatially smoothed at 6mm FWHM), high-pass filtered (0.01Hz), and denoised using CompCor [69] and participant-specific motion parameters and outliers. First-level analyses were performed as a weighted-GLM. At the second level, ROI-ROI analyses were conducted to determine whether personalized interest changed interactions between nodes of the language network as compared to neutral stories. Functional Network Connectivity multivariate statistics [70] were used to analyze the set (network) of connections, thresholded at the cluster level with a FDR-corrected $p<0.05$ with a post-hoc uncorrected connection-level $p<0.05$. Within-group matrices representing correlation values were visualized using the CONN toolbox.

Whole Brain fMRI Analyses. Whole-brain analyses were conducted to determine whether personal interests activated regions outside of canonical language regions. Group-level modeling was performed using SPM12. One-sample t-tests were used to determine regions for which activation in condition of interest (NEUTRAL, INTEREST, INTEREST > NEUTRAL) was

greater than baseline. Group maps were thresholded at an uncorrected voxel $p < 0.001$, with a cluster correction for multiple comparisons (FWE < 0.05).

Voxel-wise overlap and regional consistency analyses. A group-constrained subject specific (GCSS) approach was used to assess consistency and spatial overlap in activation patterns across different conditions [29,31]. Each participant's statistical parametric map of INTEREST > NEUTRAL was thresholded voxelwise at $p<0.001$ (uncorrected) and binarized. Binarized maps were overlaid to create a probability map of regions engaged more by INTEREST than NEUTRAL narratives, which were smoothed at 6mm FWHM and thresholded voxelwise at n=2 subjects. Probability maps reflect the number of participants showing overlap in a particular voxel. Secondly, a watershed algorithm from the SPM-SS toolbox was applied to detect local probability maxima from probability maps and extend them spatially to create functionally-defined parcels. To identify regions within which a large number of participants showed significant activation, we retained parcels which contained significant voxels from 80% or more of participants.

Preregistration. The main hypotheses for the current study were included as part of a broader preregistration in 2018 for a study investigating the neural correlates of personal interest in visual, reward, and language domains in neurotypical and autistic children: https://osf.io/nr3gk. Though beyond the scope of the current study, the planned study included additional groups (e.g., including a neurotypical group with general but not specific interests), as well as a video task and associated analyses that are not presented here. For the analysis of the personal interest language task, we deviated from the preregistration by not using subject-specific functional ROIs

(NEUTRAL>BACKWARDS), as this would have precluded a comparison between our conditions of interest (INTEREST vs. NEUTRAL). Instead, we used *a priori* ROIs and whole brain analyses. The following hypothesis were tested and confirmed: 1) All children will show greater activation in the language network for personally-interesting than neutral narratives, and 2) All children will show greater activation in the reward network for personally-interesting than neutral narratives. Although we hypothesized that there would be group differences, we did not find any. Lastly, we did not test hypotheses related to association between neural and behavioral measures due to smaller than anticipated sample sizes as a result of the COVID-19 pandemic and related data acquisition and personnel limitations.

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AUTHORSHIP CONTRIBUTIONS

AMD and JDEG conceptualized the study. AMD, HAO, and KTJ designed the experiment. HAO recorded all audio stimuli. HAO, AMD, KTJ, IRF, and SN collected data. HAO and AMD analyzed the data. HAO and AMD wrote the initial draft of the manuscript. KTJ and JDEG edited the manuscript.

COMPETING INTERESTS

The authors have no competing interests to declare.

MATERIALS AND CORRESPONDENCE

Data and materials are available on OSF (https://osf.io/dh3wq/). Correspondence should be addressed to Halie Olson (holson@mit.edu) and Anila D'Mello (anila.dmello@utsouthwestern.edu).