Changing Brains Formative Evaluation Report

Allison Anderson

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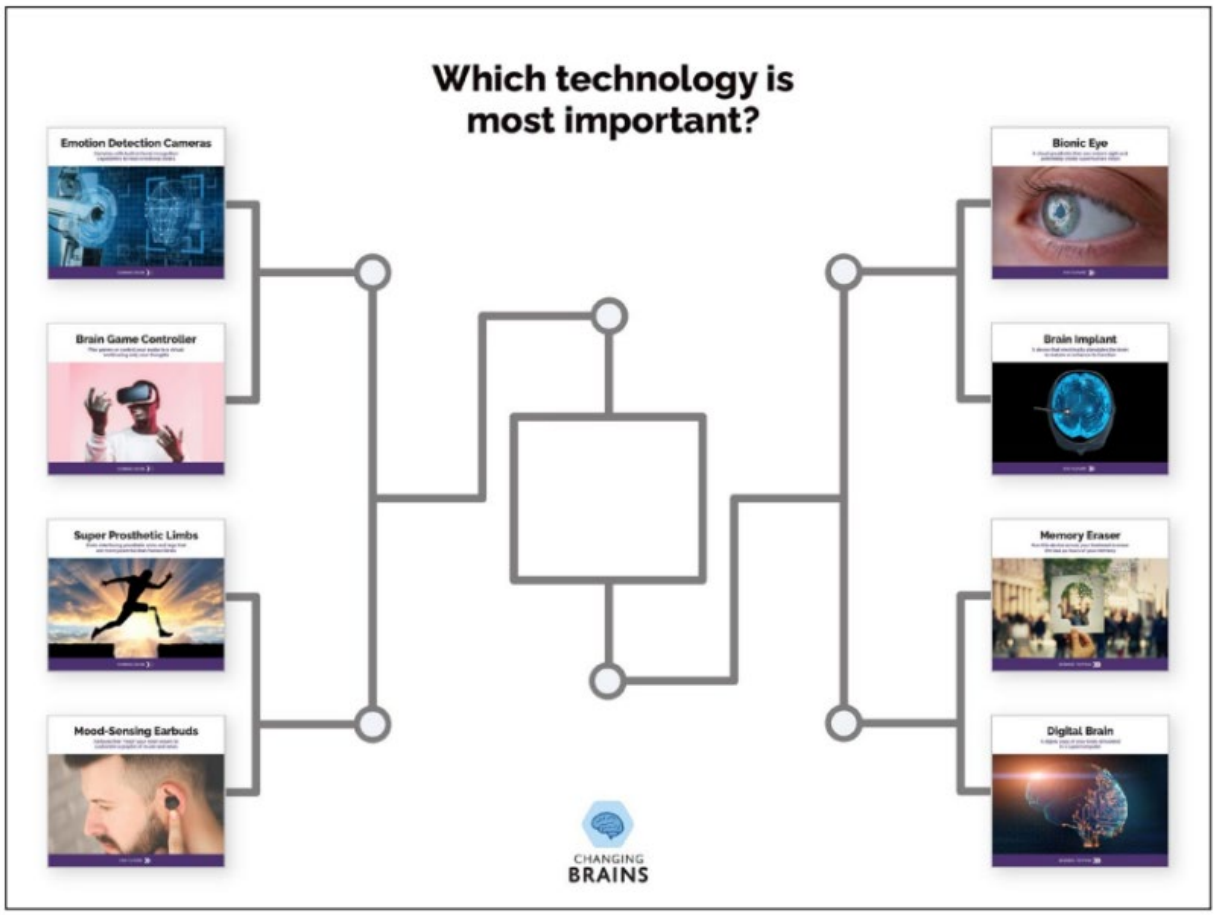

Bracket for the "Neuro Futures Championship" game

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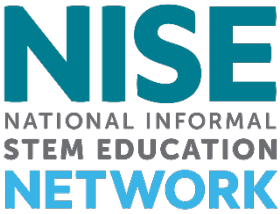

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1. Introduction

1.1 Overview

The Changing Brains project explored opportunities to engage public audiences around neuroethics though a partnership between the National Informal STEM Education Network (NISE Network), the Dana Foundation, and the Civic Science Fellows Program. The overarching goal of the project was to develop the potential for stakeholder input into neuroscience research and policy making with public audiences. To achieve this end, the experiences developed by the project created opportunities for participants to:

- practice personal attributes (e.g., curiosity, creativity and imagination, and reflexivity);
- practice interpersonal skills (e.g., communication, collaboration, and empathy);
- strengthen their sense of self-efficacy in discussing neuroscience topics and sharing personal values related to the topics; and
- increase their awareness of neuroethical issues and questions.

This report covers the formative evaluation for Phase 2 of the project, which involved the development of experiences for public audiences. Experiences were grouped into broad engagement activities (three short hands-on activities designed for public audiences in a variety of settings) and deep engagement programs (one evening program designed for adult audiences to engage deeply in the topic with scientists). Through an additional partnership, the project also supported the development of arts engagement experiences, not covered in this evaluation. The formative evaluation for the Changing Brains project addressed how the broad engagement and deep engagement experiences could be improved to meet the project goals (above) along with activity or program specific goals around learning, engagement, or usability, as needed. As such, the study was primarily intended to provide feedback for developers to:

- understand how participants interacted with the activities, in order to inform changes or improvements;
- learn to what extent participants are meeting learning objectives; and
- uncover interesting questions for future investigation.

1.2 Changing Brains experiences

One deep engagement experience was developed for the Changing Brains project, the "Brain Enhancement Conversation Lab" hosted by The Franklin Institute. This was a public program designed for adults in informal settings, such as science centers or museums, which involved bringing together scientists and members of the community. Three facilitated activities were developed as broad engagement experiences for the Changing Brains project and included in formative evaluation. These were all were developed for use with adults, teens, and families in a variety of settings, such as science centers or museums.

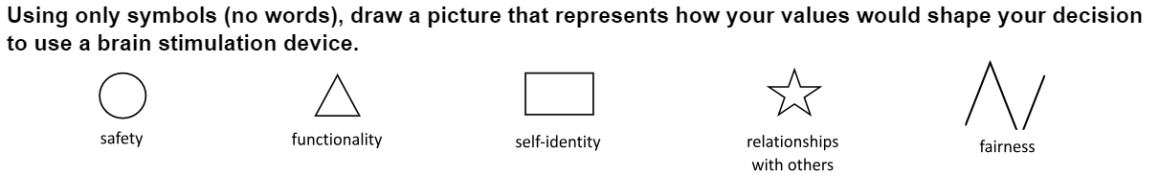
All these activities shared four **learning objectives**, that participants would understand that:

- People's values determine which technologies are developed and used.
- New technologies change society, sometimes in unexpected ways.
- Scientists, engineers, and designers use their creativity to invent things and imagine the future, just like you do.
- Brain research benefits from many perspectives, including yours.

1.2.1 Brain Enhancement Conversation Lab

The Brain Enhancement Conversation Lab was a pilot for a forum-style program that connected scientists and public audiences to discuss current science topics. This was an evening event held November 9, 2022 at the Franklin Institute. A fee was associated with attending the event ($10 for non-members, $5 for members), and a cash bar with drinks and light fare were available. The event featured scientists from UPenn brainSTIM Center, who shared vignettes and talked about technology related to brain enhancement and cognitive enhancement. Discussions about technology primarily revolved around both technology and societal implications of having access to or using technology. During the program, participants identified their values through a drawing and storytelling activity, see Figure 1 for the activity prompt. Participants had table discussions about personal and community values. These discussions involved scientists or researchers in a brain-science related field, undergraduate students, and community members. After the program, participants had an opportunity to explore the museum's *Your Brain* exhibition.

Figure 1. Prompt for values activity



The program encouraged participants to explore two **big questions:**

- Is cognitive enhancement an acceptable use for neurostimulation technology?
- How do values and social context influence what is acceptable?

1.2.2 "Neuro Futures" and "Neuro Futures Championship" games

The two Neuro Futures games are both facilitator-led conversation activities, inviting participants to explore their opinions and values about future brain technologies. Both games share a set of twelve technologies for participants to explore, such as mental health screening, a bionic eye, smart pills, and a brain game controller. Each technology card identifies the technology and includes a one-sentence description of the technology, a short paragraph discussing the technology, questions about application or use of the technology, and an indication how probable the technology is (coming soon, far future, or science fiction). See Figure 2 for an example technology card and Table 1 for a list of all technologies included. Throughout the evaluation, the same technologies were tested, with changes to what types of information were provided and what level of detail was included. Additionally, both activities encourage visitors to explore two **big questions:**

- How might future brain technologies change our society?
- How can we include many diverse perspectives and priorities in the development of brain technologies?

Figure 2. Example technology card: mental health screening

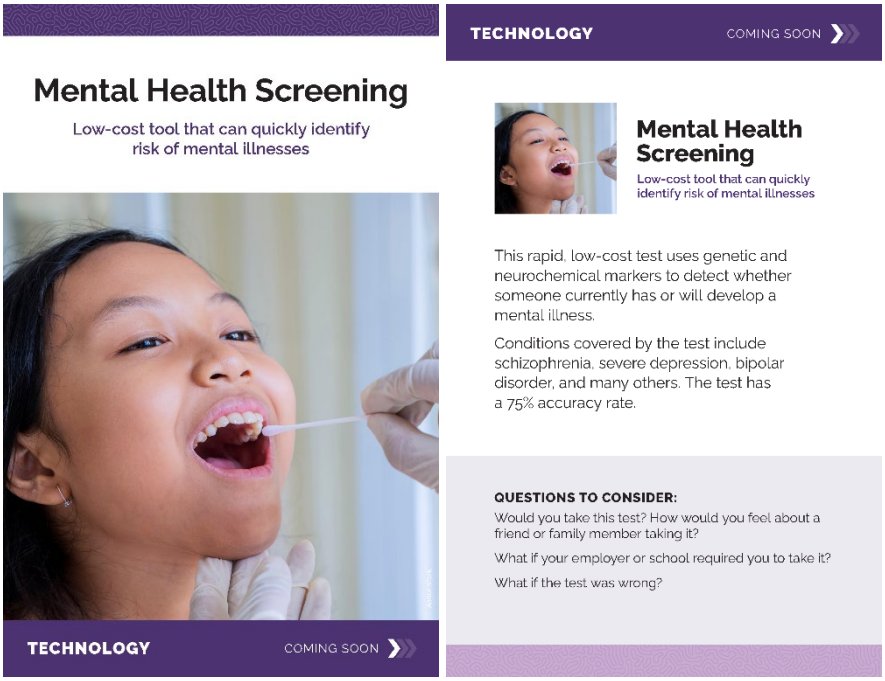


Table 1. Technologies included in both "Neuro Futures" and "Neuro Futures Championship" card games.

Technology	Short description	Probability
Smart Pills	Pills for boosting memory and attention that could make you smarter	Coming Soon
Emotion Detection Cameras	Cameras with built-in facial recognition capabilities to read emotional states	Coming Soon
Super Prosthetic Limbs	Brain-interfacing prosthetic arms and legs that are more powerful than human limbs	Coming Soon
Brain Game Controller	Play games or control your avatar in a virtual world using only your thoughts	Coming Soon
Mental Health Screening	Low-cost tool that can quickly identify risk of mental illnesses	Coming Soon
Designer Brain Cells	A mix of human and animal brain cells used to grow replacement brain tissue	Far Future
Mood-Sensing Earbuds	Earbuds that "read" your brain waves to customize a playlist of music and news	Far Future
Brain Implant	A device that electrically stimulates the brain to restore or enhance its function	Far Future
Bionic Eye	A visual prosthetic that can restore sight and potentially create superhuman vision	Far Future
Memory Eraser	Run this device across your forehead to erase the last 24 hours of your memory	Science Fiction
Digital Brain	A digital copy of your brain simulated in a supercomputer	Science Fiction
Pocket Lie Scanner	Handheld device that scans a person's brain to reveal whether they are lying	Science Fiction

The "Neuro Futures" card game invites players to distribute resources to potential neurotechnologies from their own perspective, and then from a provided character's perspective. In addition to the technology cards described above, this game includes a set of people cards with personas representing various backgrounds and perspectives. Each card includes a picture and description of the person, including their name, pronouns, age, occupation, and interests, along with a short scenario and insight into their hopes for the future. See Figure 3 for an example character card and Table 2 for a list of all people cards with their name and short description.

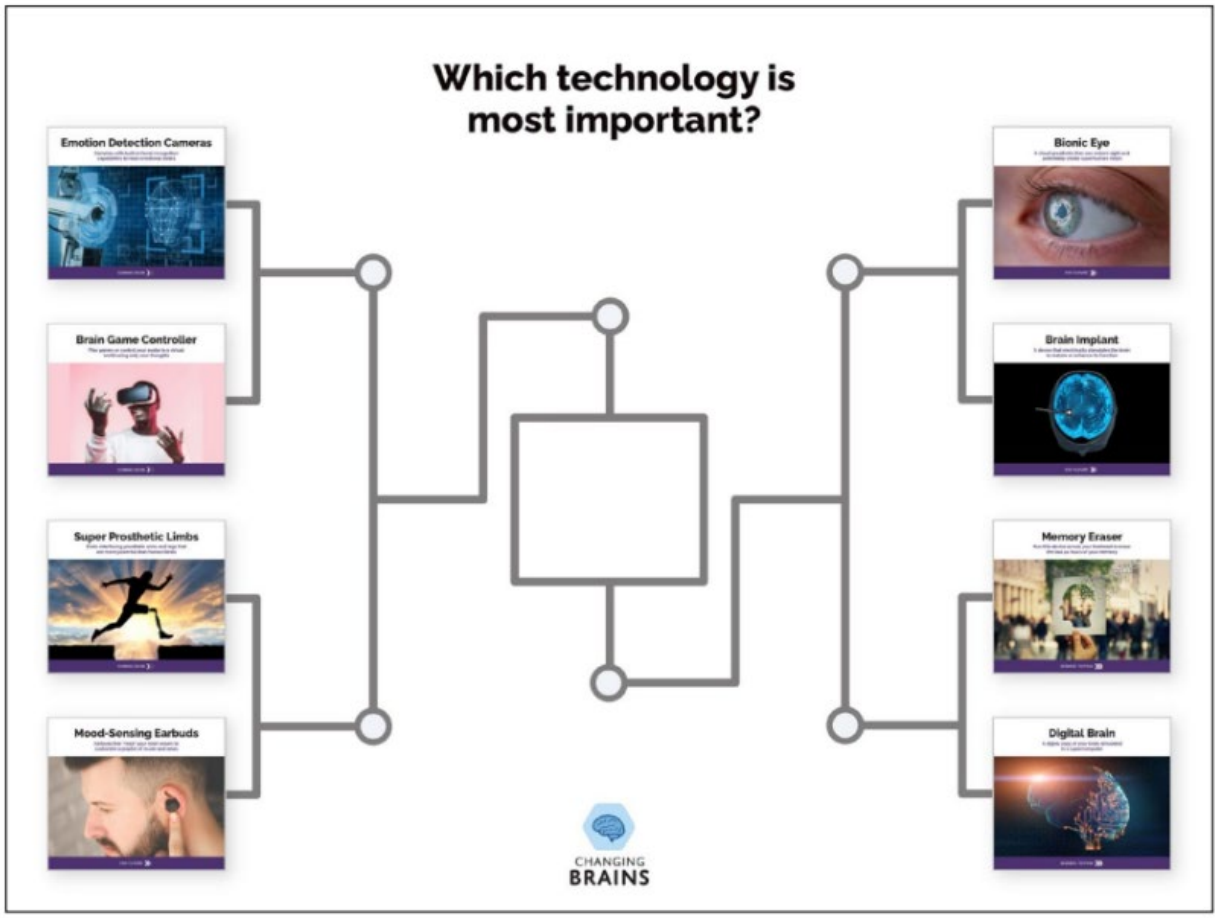
Figure 3. Example character card: Edith

Table 2. Characters included in the "Neuro Futures" card game

Person	Short description
Darren	School counselor concerned about the rise of mental health problems in his students
Sarah	Military veteran suffering from post-traumatic stress disorder (PTSD) and a serious leg injury sustained during service
Kim	Mother of a 6-year-old child with a rare neurological disease
Jacquie	Experienced lawyer who believes in the importance of achieving justice
Adriana	High school junior hoping to get a scholarship to a good college
Malik	Middle school student and aspiring future video game designer
Kris	Surgeon frustrated by the lack of options for patients with brain damage
Chris	Controversial podcast host who enjoys creating a stir
Lisa	Caregiver for her elderly mother with Alzheimer's disease
Ricky	Computer hacker with little concern for laws or ethics
Edith	Elderly retired professor who misses her more youthful days
Robert	Military general leading secret operations to test experimental technologies

The "Neuro Future Championship" game invites consideration and conversation about the implications of neurotechnologies by making decisions about technology through a tournament bracket. This game includes an alternative version of the technology cards that show the name, a one-sentence description, and an indication how probable the technology is (coming soon, far future, or science fiction). These simplified cards are used for the bracket, and the more detailed cards can be included for more information or left out. To set up the game, the facilitator either randomly or strategically chooses eight of the 12 cards. A facilitator leads the group through a conversation comparing pairs of technology cards to decide which they feel is most beneficial or important and why. See Figure 4 for an example of the bracket set up and ready to start.

Figure 4. "Neuro Futures Championship" game bracket example set up



For more information about the final versions of the activities, visit the NISE Network website:

- "Neuro Futures" card game: https://nisenet.org/catalog/neuro-futures
- "Neuro Future Championship" game: https://nisenet.org/catalog/neuro-futures-championship

1.2.3 "What Makes Us Human?" card game

The "What Makes Us Human?" game is a facilitator-led conversation activity, inviting participants to consider which abilities are most uniquely human, then design a robot incorporating those abilities. Materials for the game include two sets of cards (ability cards and robot cards) and tokens for allocating resources. The ability cards, shown in Figure 5, consist of 10 words or phrases (e.g. decision making, communication, senses) and related iconography, with two anchor cards to indicate which are most and least uniquely human. Each of the 12 robots has a role (e.g., Robot Teacher, Robot Firefighter) with an image and a short description about its purpose. On the back of each card is a scenario for the robot to react to and a discussion prompt. See Figure 6 for an example robot card and Table 3 for a list of all robot cards with their short descriptions.

Figure 5. Ability cards for "What Makes Us Human?"

Figure 6. Example robot card: Robot Teacher.

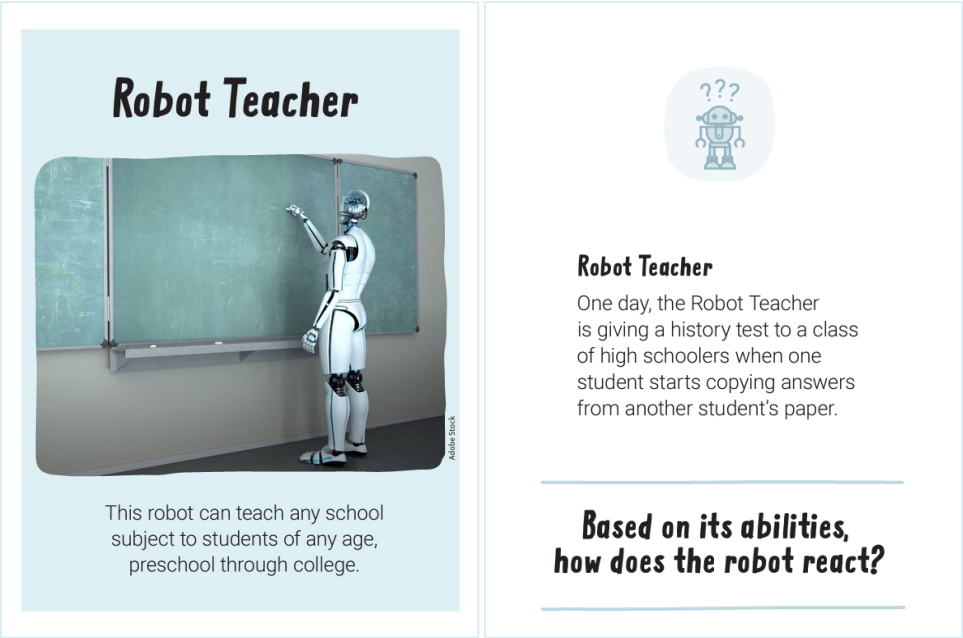


Table 3. Robot cards included in "What Makes Us Human?"

Person	Short description
Robot Caregiver	This robot helps elderly people live independently by assisting with mobility and household tasks as well as helping to prevent loneliness.
Robot Teacher	This robot can teach any school subject to students of any age, preschool through college.
Robot Artist	This robot creates beautiful works of art for people to enjoy in museums or to buy for their homes.
Robot Best Friend	This robot is the perfect friend, able to play your favorite games and talk about your favorite things, and is always there for you.
Robot Doctor	This robot can diagnose and treat all kinds of diseases and injuries while also providing helpful information to patients.
Robot Firefighter	This robot can enter burning buildings and other dangerous situations to rescue people as well as help to put out fires.
Robot Nanny	This robot can entertain and take care of babies and children while their parents are busy.
Robot Chef	This robot can prepare hundreds of different meals and even invent delicious new recipes.
Robot Lawyer	This robot assists people with legal matters, including arguing on their behalf in the courtroom.
Robot Factory Worker	This robot can perform a wide variety of manual tasks quickly and accurately.
Robot Inventor	This robot can perform a wide variety of manual tasks quickly and accurately.
Robot Dog-Walker	This robot takes good care of your pets while you are away, keeping them happy and healthy.

In the first round of the game, participants rank the ten attributes from most to least human, with the facilitator prompting discussions about why they are uniquely human or how many traits are required to be human. In the second round, participants allocate resources by placing tokens on the abilities to indicate what they would prioritize if they were creating a super advanced robot. After the resources are allocated, the facilitator gives them a robot card, giving them a chance to rearrange the tokens, before talking through how the robot would react to the given scenario.

The activity encourages visitors to explore two **big questions:**

- What does it mean to be human? What is unique about the human brain?
- How human-like could machines become? What would be the risks/benefits?

For more information about the final version, visit the NISE Network website: https://nisenet.org/catalog/what-makes-us-human

2. Methods

Formative evaluation focused on making changes to products developed for the Changing Brains project. The study was found to be exempt by the Arizona State University institutional review board. Methods for evaluating experiences include team-based inquiry, surveys, observations, and interviews, discussed in the sections below.

2.1 Team-Based Inquiry

Prior to the formative evaluation discussed in this report, the project team used team-based inquiry (TBI)[1] to initially assess and improve the broad engagement activities. TBI is a process developed by the NISE Network to allow project teams or education professionals to iteratively test and improve their products to more effectively engage audiences (Pattison, Cohn and Kollmann, 2014). While working on the hands-on activities, the project team took observation notes and documented facilitator reflections. Inquiry was focused on usability and engagement, to help the developers make adjustments to what technologies were included, refine definitions or descriptions, and fine-tune to game play.

2.2 Brain Enhancement Conversation Lab Survey

Evaluation for the Brain Enhancement Conversation Lab consisted of a post-survey directly after the event. Participants were given the option to either complete a paper copy or online version of the survey. Almost all respondents chose to answer the physical version. The survey addressed participants' overall impressions of the event and goals around the event being welcoming, a space safe for discussing personal values, and trustworthy. Participants were also asked questions related to opportunities to practice the personal attributes important for neuroethics engagement (curiosity, creativity, reflexivity, communication, collaboration, and empathy); their awareness of neuroethical issues and questions; and to describe themselves in terms of their age, gender, race/ethnicity, education, and connections to brain science. For the full instrument, see Appendix A.

2.2.1 Data analysis

Analysis for the Brain Enhancement Conversation Lab focused on descriptive frequencies for quantitative responses. Inductive coding, which involves "immersion in the details and specifics of data to discover important patterns, themes, and interrelationships" (Patton, 2002), was used for the two open-ended questions.

Expecting a ceiling effect -- that this program might make a bigger impact on people who had less knowledge or experience in the field of brain science -- exploratory analysis using descriptive statistics was used to compare people who were scientists, researchers, or graduate students in a brain-science related field ("scientists" n=18) and those who self-identified as "community members" or "other" ("community" n=16). In general, the variation between how these two groups responded was proportionally similar, however in a few areas their responses differed enough to be worth calling attention to. This is a small sample size, so these differences are suggestive and may be worth exploring more in a larger study. When present, these differences are included with the main findings.

[1] For more information about TBI, see http://www.nisenet.org/catalog/tools_guides/team-based_inquiry_guide

2.2.2 Sample Description

Approximately 50 people attended the event, including scientists and researcher, and of these, 34 completed the survey directly after the event. Participants were well-educated adults, representing both scientists and community members.[2] All had completed at least a college degree and the majority had completed graduate school, see Figure 7 and Figure 8. Survey respondents were fairly homogenous in terms of race/ethnicity and age, as most identified as white and between 25 and 44 years old, see Figure 9 and Figure 10. They were also about equally split between men and women, see Figure 11

Figure 7. Responses to "What is your role?" (N=34)

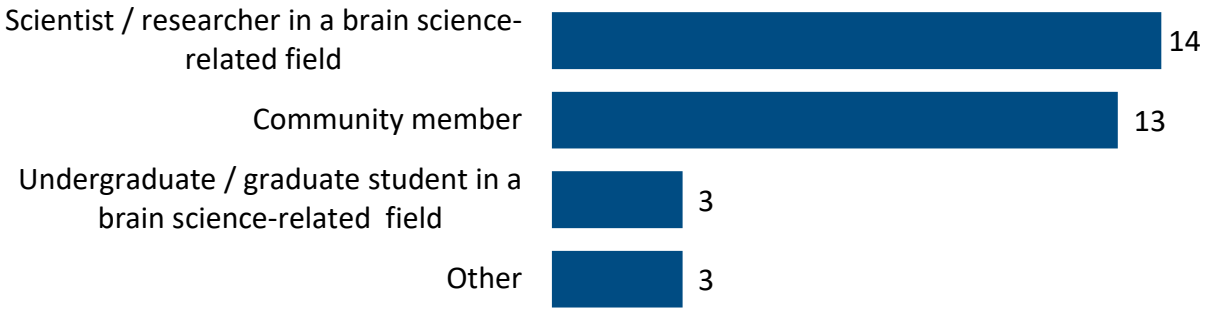


Figure 8. Responses to "What is your highest level of education completed?" (N=34)

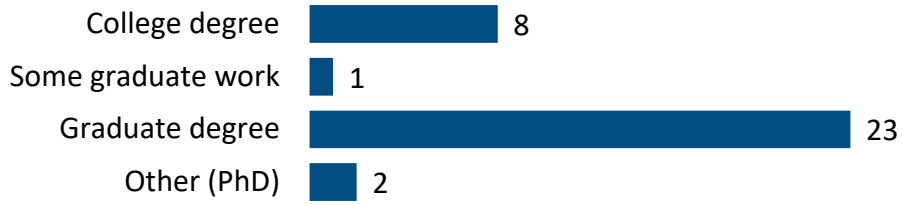
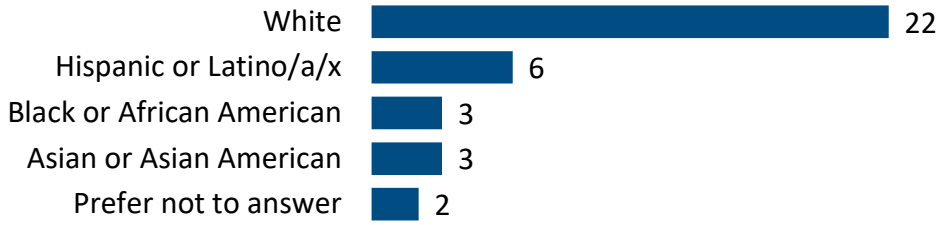


Figure 9. Responses to "With which racial or ethnic group(s) do you identify?" (N=34)[3]



[2] "Other" Roles included "cognition professional" and "wife of a lab researcher", suggesting that these people were indicating that they had related knowledge that straddled being a scientists/research and a community member.

[3] The options "American Indian or Alaskan Native," "Native Hawaiian or Pacific Islander," and "Prefer to self-describe" were not selected by any participants.

Figure 10. Responses to "What is your age?" (N=34)

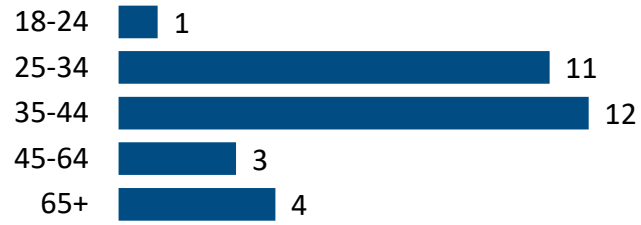
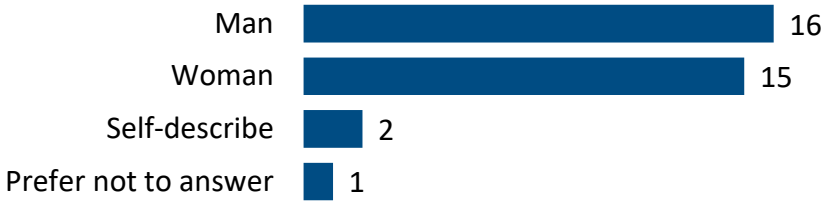


Figure 11. Responses to "What is your gender identity?" (N=34)



2.3 Broad engagement activities

Formative evaluation was completed for the three broad engagement experiences after iterative development using TBI. Once they were in their final stage of development, visitors at the Arizona Science Center were observed using the activities and invited to participate in a short interview, see Table 4 for the testing summary. Each activity was tested with two facilitators, to look for differences between educators. Taking into account the small sample size, no notable differences were present between the facilitators, but their reflections contributed to improvements for the facilitation guide.

Visitors were recruited using continuous random sampling, inviting every eligible group to play the game and participate in evaluation. Eligible visitors included adult-only and family groups visiting the Arizona Science Center, with at least one participant over 8 years old. Verbal consent was obtained from adults for themselves or their children, and additional verbal assent obtained from participants under 18. The observations focused on the three interpersonal skills (communication, collaboration, and empathy) and three personal attributes (curiosity, creativity and imagination, and reflexivity), discussed in more detail in Section 3. Data collectors looked for evidence of these behaviors and noted what aspects of the activity related to their behaviors. Interviews addressed interest in the activities, success of learning objectives, reflection on game elements, and general feedback, with basic age and gender demographics for the survey respondent and their group. All three activities used the same instruments, with minor language adjustments to refer to specific elements of the card games, see Appendix B.

Table 4. Hands-on activity summary

Activity	Testing dates	Sample size
"Neuro Futures"	December 20-21, 2022	14 groups
"Neuro Futures Championship"	December 29, 2022 – January 2, 2023	17 groups
"What Makes Us Human?"	January 13-14, 2023	16 groups

2.3.1 Data analysis

Observations and interviews were primarily coded using deductive coding, which involves looking for themes related to the evaluation questions (Fereday & Muir-Cochrane, 2006). For this project, responses were coded using the six attributes for neuroethics engagement that were a focus for this project. These included three interpersonal skills (communication, collaboration, and empathy) and three personal attributes (curiosity, creativity and imagination, and reflexivity), see Section 3 for more details. These categories were then further refined using the observation data, data collector and facilitator reflections, and conversations with the project team. Inductive coding (Patton, 2002) was used in conjunction with the deductive coding scheme when visitor responses could not be categorized using the pre-defined themes. Findings from these qualitative analyses were used to either support, explain, or describe the quantitative survey results.

Quantitative data were analyzed using descriptive statistics. Throughout the report, data have been summarized across the three broad engagement activities for shared measures or goals. They have been grouped when doing so simplifies reporting, and each activity has been color coded in the charts to show the differences. The sample sizes are too small to make significant comparisons between the activities; however, differences between the activities may indicate areas for future research.

2.3.2 Observation and interview participants

The activities were designed to be used primarily with teens and adults, though some younger children were observed being able to meaningfully engage in the activities. Across the three activities, 47 groups participated in observations alone or observations paired with interviews. Participants included mostly intergenerational groups and were slightly more likely to be families with younger children (0-11), than adult-only groups or families with older children (12-17), see Figure 12. Across the 47 groups, a total of 137 people tried the activities, with multiple people within each group providing feedback about their experience. Overall, two-thirds of visitors who tried the activities were adults, see Figure 13. Just over half of visitors identified as female, with most of the rest identifying as male, see Figure 14.

Figure 12. Group type for visitors using the three broad engagement activities (N=47)

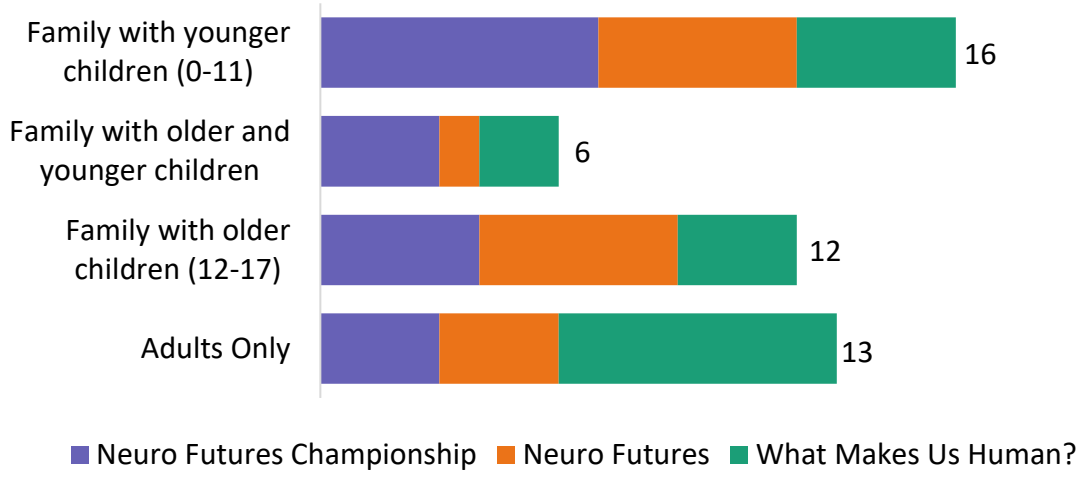


Figure 13. Ages for visitors using the activities (N=47 groups or 137 individuals)

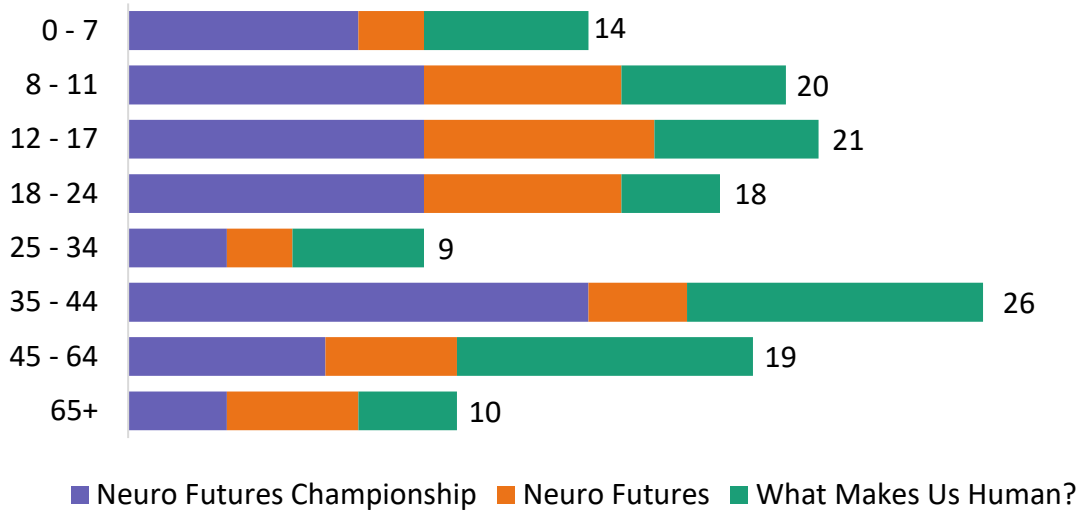
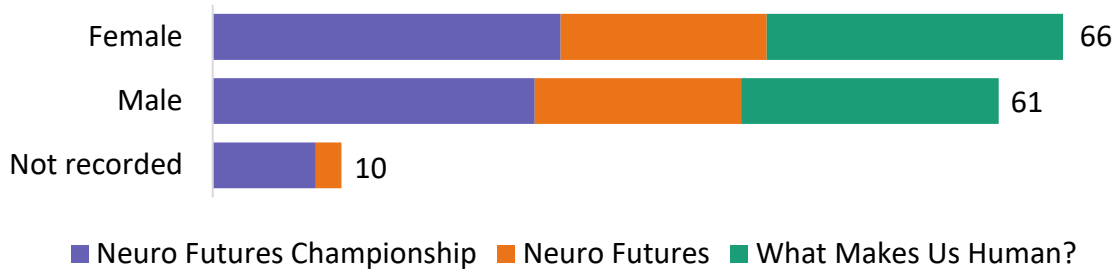


Figure 14. Gender identity for visitors using the activities (N=47 groups or 137 individuals)



3. Attributes for neuroethics engagement

3.1 Defining attributes for neuroethics engagement

Drawing on prior work, including existing literature and insights from project advisors, the team developed definitions for the personal attributes and interpersonal skills (Das et al, 2022). These behaviors were selected for their importance in engaging with neuroethics and for their ability to be practiced during both broad and deep engagement activities. The behaviors were further refined by the evaluator and project team so that they could be directly observed in informal learning settings, both to set realistic expectations for the behaviors and be used as a coding scheme for analysis (Boston Children's Museum, N.D.). Icons are included to follow which findings were being discussed when moving back and forth through the data.[4] Figure 15 and Figure 16 below includes the behaviors, working definitions, and related icons.

Figure 15. Attributes for neuroethics engagement: interpersonal skills

Interpersonal Skills

Communication

Visitors share their opinions and perspectives relevant to the activity's topic, either with other visitors or the facilitator, and listen or respond to others' opinions and perspectives. Ideally, when practicing effective communication, the visitor's point is understandable and open to discussion or feedback.

Collaboration

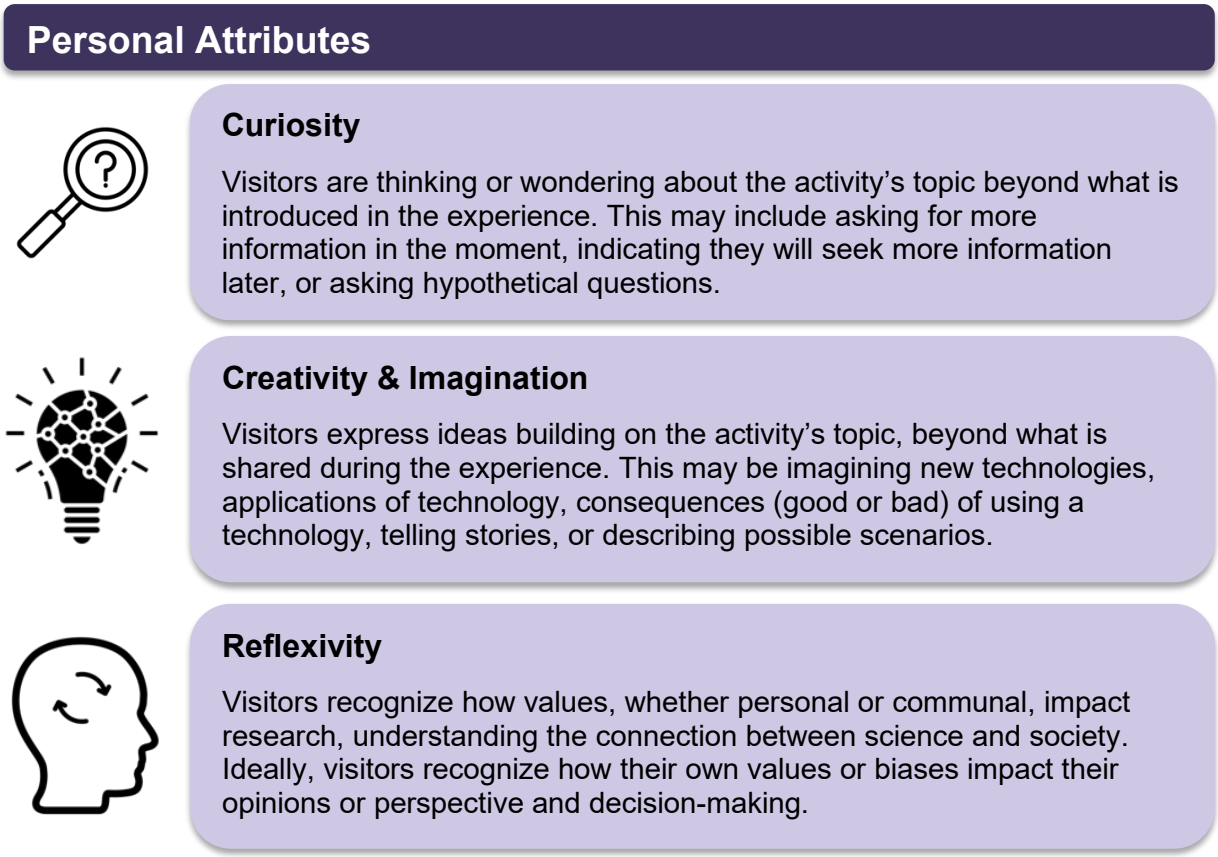
Visitors work together to make a decision or solve a problem that is relevant to the activity. In the absence of other group members, a visitor may collaborate with a facilitator. This is closely tied to communication.

Empathy

Visitors share their understanding of another person's perspective or experience, considering how technology might benefit, harm, or otherwise impact that person. This may look like compassion, or a broad desire to be helpful or beneficial to others.

[4] All icons obtained from Noun Project under their creative commons license. Communication by Soetarman Atmodjo; Teamwork and Creativity by ProSymbols; Empathy by Gonzalo Zaragoza; Magnifying Glass by Sunardi; and Thinking by corpus delicti.

Figure 16. Attributes for neuroethics engagement: personal attributes



3.2 Emergent findings for correlations between design strategies and opportunities for visitors to practice personal attributes or interpersonal skills.

Observation data provided preliminary evidence that specific design strategies may support visitors' practicing the behaviors related to personal attributes or interpersonal skills. These connections were drawn from facilitator reflections, as well as visitor observations, and suggest strategies that can be leveraged to influence participant outcomes. Table 5 below shows the emergent connections.

Some strategies seemed to relate to multiple interpersonal skills or personal attributes. Requiring participants to make a decision as part of the activity appeared to encourage or provide opportunities for visitors to communicate or collaborate with each other, as well as practice empathy, creativity and imagination, and reflexivity. Including character cards with a variety of perspectives, and having visitors use characters with different perspectives from their own, appears to drive moments of empathy, curiosity, or reflexivity. Providing clear, concise information, appeared to spark curiosity or creativity and imagination.

Other strategies seemed to relate to only one skill or attribute. Prompting questions about what makes someone human seemed to spark empathy. Facilitators describing simple scenarios seemed to prompt creativity and imagination. Lastly, including a variety of technologies or variables to consider appeared to encourage collaboration between visitors. A more in-depth study would be beneficial, in order to draw clearer connections between design strategies and participant behaviors.

Table 5. Possible connections between design strategies for broad engagement activities and the interpersonal skills or personal attributes they support.

	Communication	Collaboration	Empathy	Curiosity	Creativity & Imagination	Reflexivity
Requiring participants to make a decision	X	X	X		X	X
Using character cards with different perspectives			X	X		X
Including clear but limited information				X	X	
Prompting questions about what makes someone human			X			
Facilitator sharing a simple scenario					X	
Including a variety of technology or attributes		X				

4. Brain Enhancement Conversation Lab findings

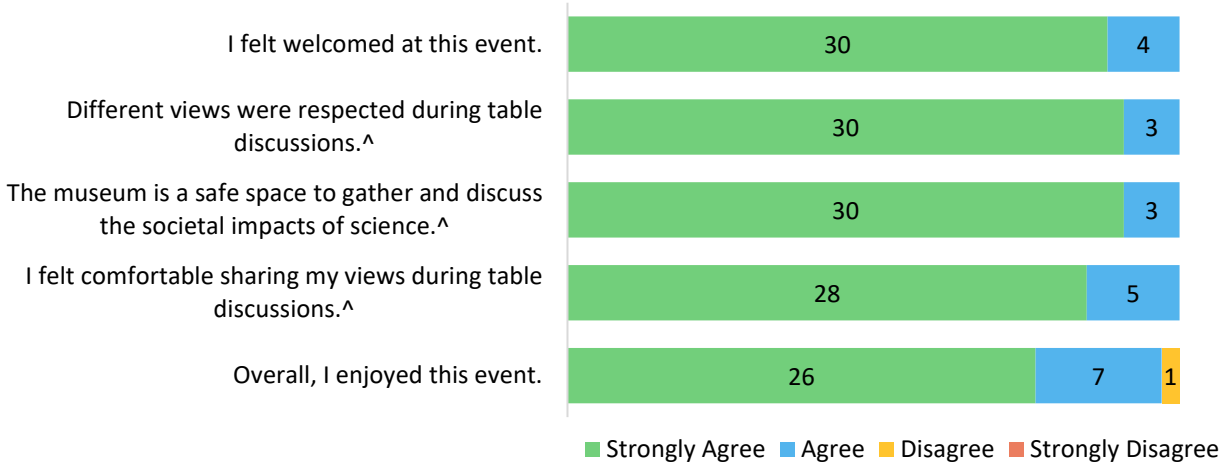
This section shares findings from the formative evaluation for the deep engagement program, the Brain Enhancement Conversation Lab (referred to as the conversation lab or event). Although the findings represent feedback for a single event, exploratory analyses indicated that there may be differences in outcomes for participants based on their prior experience with the topic. These differences are explored in the findings below; however, more research should be done to understand the impacts of prior experience on participant outcomes in an event like this.

4.1 Overall impressions

4.1.1 Participants had positive feelings about the conversation lab and valued the variety of perspectives included in the event, the discussion format, and learning new or useful information.

Overall, participants indicated that the conversation lab was welcoming and comfortable event, see Figure 17. Most participants strongly agreed that they felt welcomed at the event (30 people "strongly agreed"). They also indicated that the event was a comfortable and safe space, where different views were respected during discussions. In a few areas, the scientists (n=18) more enthusiastically agreed with the statements than general community members (n=16), being slightly more likely to strongly agree that they enjoyed the event overall ("Strongly agree": 17 scientists, 9 community members) and felt comfortable sharing their views ("Strongly agree": 17 scientists, 11 community members).

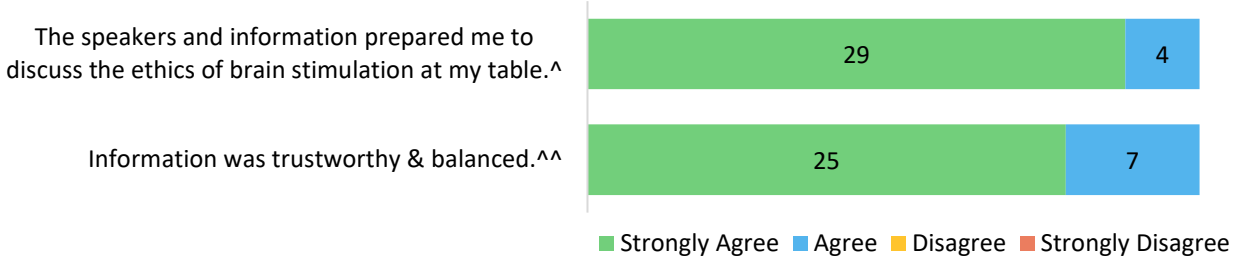
Figure 17. Overall impressions of the event (N=34)[5]



Overall, all participants agreed that they were provided the information needed to participate, and that the information was trustworthy, see Figure 18. While everyone at the event agreed with the statements, this was an area where scientists more emphatically agreed, all scientists (n=17) "strongly agreed" to both statements. However, community members (n=16) were less enthusiastic, with 12 community members strongly agreeing that they felt prepared to discuss the ethics of brain stimulation and 8 strongly agreeing that the information was trustworthy.

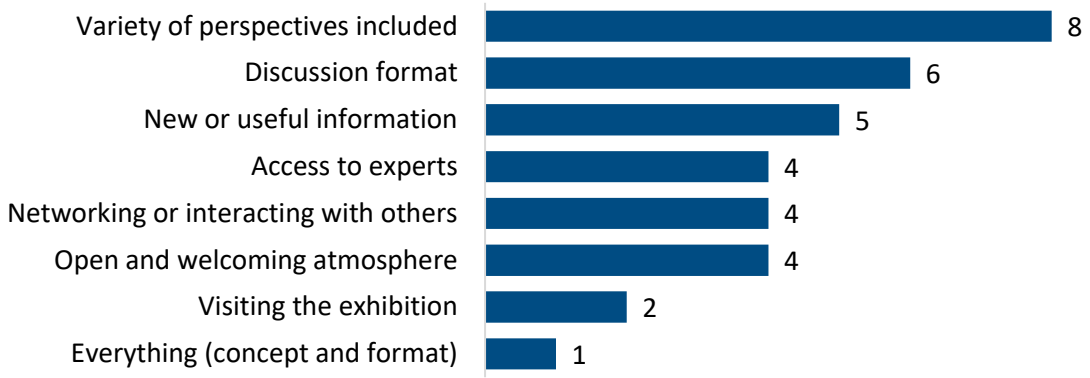
[5] ^n=33

Figure 18. Overall impressions of the event (N=34)[6]



In response to an open-ended question about the event, participants offered a variety of aspects that they felt were valuable, see Figure 19. Participants most commonly (n=8) talked about valuing the variety of perspectives included in the event, as one participant wrote that they valued "listening to different perspectives and levels of expertise". Participants also valued the discussion format of the event ("the discussions were excellent, thought-provoking, & open to varying") and learning new or useful information ("I had no idea brain stimulation was (1) being used clinically (2) was available for purchase on Amazon."). People who identified as scientists or graduate students in brain-science related fields (n=17) were much more likely to respond than community members or people who didn't indicate their role (n=6). This may influence what participants commonly identified as valuable; however, the sample size is too small to meaningfully compare between the two groups. influence.

Figure 19. Responses to "What did you value about this event?" (n=23)



Participants generally enjoyed the event and had limited suggestions for changes (n=20). These were primarily about the audio or visual aspects of the venue (n=13), which the project team members present at the event also noted. Other feedback included wanting more time for discussion or in the exhibition (n=3), more background information (n=1), or simply to have more events like this (n=1). One person suggested simpler instructions for the values activity.

4.2 Personal attributes and interpersonal skills

Participants rated their agreement with a series of statements related to the personal attributes and interpersonal skills. Overall, responses were positive from most participants. Across multiple survey items, scientists' responses were more likely to select "strongly agree" or "a great deal," suggesting that there may be differences in how this program served scientists versus people who considered themselves community members. Future research should investigate the

[6] ^n=33, ^^n=32

differences in impacts between scientists and community members in events like the conversation lab.

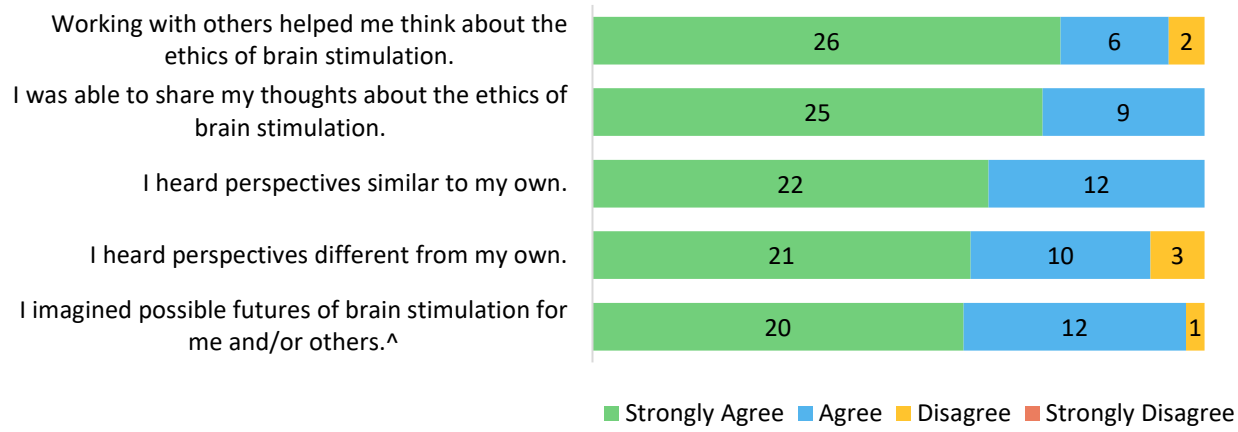
4.2.1 Most participants agreed they were able to practice collaboration and communication at the event, through working with others to think about the ethics of brain stimulation and sharing their perspectives.

Participants had the opportunity to practice **collaboration** or **communication** through table discussions. One goal of these conversations was to help people think through their ideas and work together when practicing the other attributes. They were encouraged to share their own perspectives, listen to others' perspectives, and discuss the ethics of brain stimulation. Participants were not specifically prompted to practice **empathy**, but they were encouraged to listen to others' perspectives and discuss possible futures of brain stimulation with those perspectives in mind. Overall, most participants agreed that they were able to practice these skills during the event, see Figure 20.

Participants practiced **collaboration**. Most respondents (n=26) strongly agreed that "working with others helped me think about the ethics of brain stimulation." This was an area where scientists (n=15) were more likely to "strongly agree" than community members (n=10), possibly due to how the question was worded or how prior knowledge contributed to thinking about ethics.

Participants practiced **communication** and may have practiced **empathy**. They strongly agreed (n=25) with the statement "I was able to share my thoughts about the ethics of brain stimulation." About two-thirds strongly agreed that they heard perspectives similar to (n=22) or different from (n=21) their own. Three participants felt like they did not hear different perspectives. Scientists and community members responded about the same for hearing perspectives similar and different to their own. However, scientists more strongly agreed that they were able to share their own thoughts ("Strongly agree": 15 scientists, 10 community members). Many respondents (n=20) also strongly agreed that they imagined possible futures for themselves or others, which may indicate that they practiced empathy.

Figure 20. Agreement with statements related to interpersonal skills (N=34)[7]



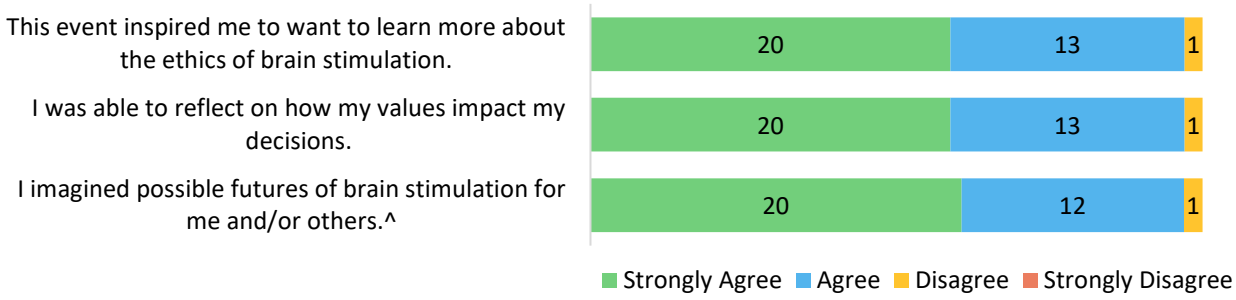
[7] ^n=33

4.2.2 *Many participants strongly agreed that they were able to practice creativity and reflexivity through reflecting on their values and imagining possible futures.*

Participants had the opportunity to practice **creativity** and **reflexivity** through an activity where they identified their values and shared a story about how that would shape their decision to use a brain stimulation device. They also could have practiced these attributes through table conversations discussing possible futures of brain stimulation. An overarching goal of the event was to inspire **curiosity** about the ethics of brain stimulation, and the event was broadly intended to support this personal attribute.

Overall, most participants agreed that they were able to practice these three skills during the event, see Figure 21. Many (n=20) strongly agreed that they imagined possible futures of brain stimulation (**creativity**); were inspired to learn more about the ethics of brain stimulation (**curiosity**); and were able to reflect on how their values impact their decisions (**reflexivity**). Scientists (n=13) were more likely than community members (n=7) to "strongly agree" that they were able to reflect on their values. It is possible that this is related to scientists' proximity to brain research or that community members need different supports to practice reflexivity.

Figure 21. Agreement with statements related to personal attributes (N=34)[8]



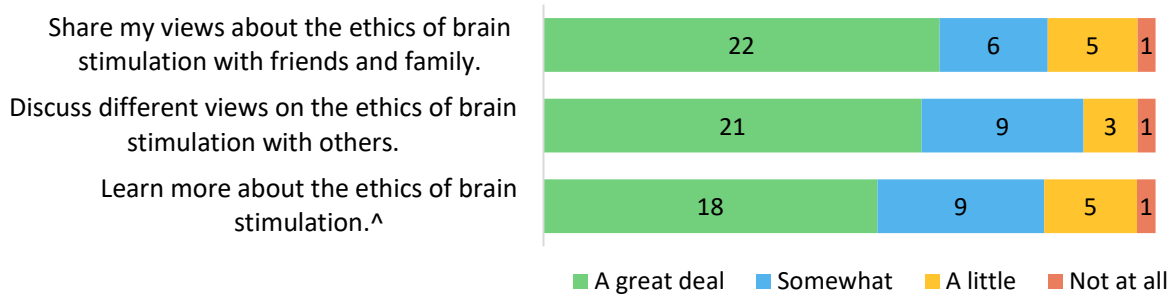
4.2.3 *Participants reported increased self-efficacy and awareness around neuroscience topics.*

Experts shared vignettes and information about technologies related to brain stimulation and cognitive enhancement. Participants then had opportunities to identify and share their values, and then discuss societal implications for these technologies. Many participants felt that they strengthened their self-efficacy "a great deal" around sharing their views about the ethics of brain stimulation (n=22) and discussing topics and values related to the ethics of brain stimulation (n=21), see Figure 22. Many also indicated that they were "a great deal" more confident in learning more about the ethics of brain stimulation (n=18).

The questions about self-efficacy initiated the comparison between scientists and community members since a ceiling effect was expected for scientists. However, for each of the three statements, scientists were more likely to say the event increased their confidence "a great deal" than the community members were. Community members' responses were more distributed across between learning "a great deal," "a little," and "a lot."

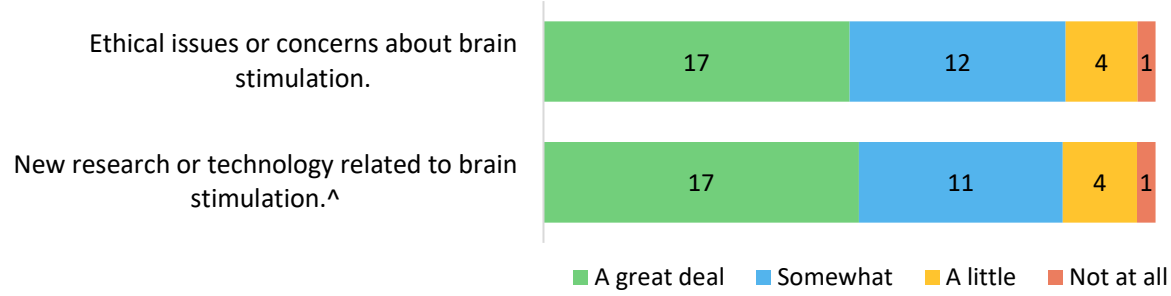
[8] ^n=33

Figure 22. Responses to "How much did this event increase your confidence in your abilities to do the following:" (N=34)[9]



About half of participants (n=17) response that the event increased their awareness "a great deal" about ethical issues or research related to brain stimulation, see Figure 23. Proportionally, scientists (9 of 18) and community members (8 of 16) were equally likely to strongly agree that they had increased awareness around ethical issues. However, scientists (n=10) were slightly more likely to select "a great deal" than community members (n=7) when reflecting on how much the event increased their awareness of new research or technology.

Figure 23. Responses to "How much did this event increase your awareness or understanding of the following:" (N=34)[10]



[9] ^n=33

[10] ^n=33

5. Broad Engagement Activity Findings

This section addresses evaluation findings for the broad engagement activities, three facilitated discussion-based card games: "Neuro Futures Championship," "Neuro Futures," and "What Makes Us Human?" Due to the shared instruments and similarity in goals, results are aggregated into charts, with each activity color coded. Comparisons between the activities highlight differences and similarities in outcomes, suggesting that a suite of activities are most effective at achieving a wide array of goals.

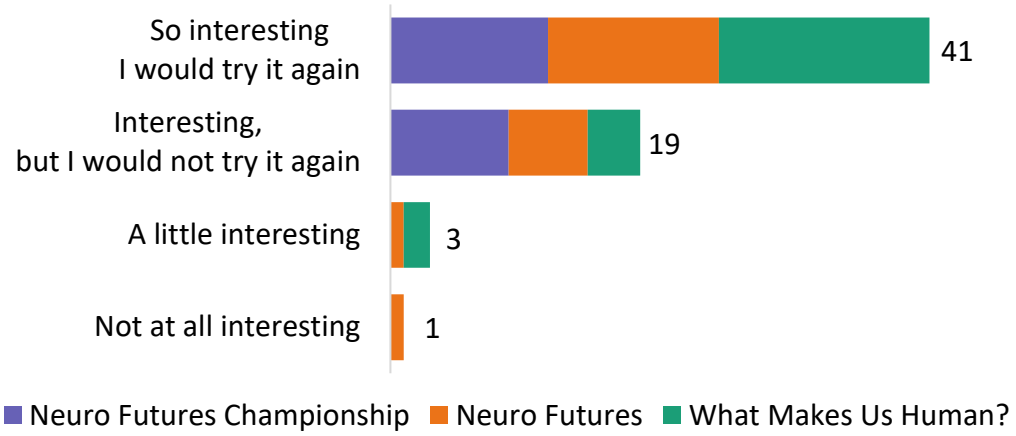
5.1 Usability, accessibility, and confusion

Overall, the three activities worked well for most visitors, with no physical usability issues reported. During observations, (11 of 47 groups) some groups showed evidence of confusion, however in all cases it appeared that facilitators were able to clarify in the moment to not detract from the experience. Some visitors required additional clarification for the instructions (n=6), needed to have words re-defined (n=3), or needed clarification about how a technology was described (n=2). For "What Makes Us Human?" a few visitors had trouble understanding the rules and intent of the game, to the extent that the facilitator needed to simplify the discussion. These visitors included young children (under 8) or adults who appeared to have undisclosed cognitive disabilities. While they were able to participate, and reported enjoying the game, they may not have the same outcomes as would be expected with the target audience of older children and adults who engaged in the discussion as designed.

5.2 Interest and improvements

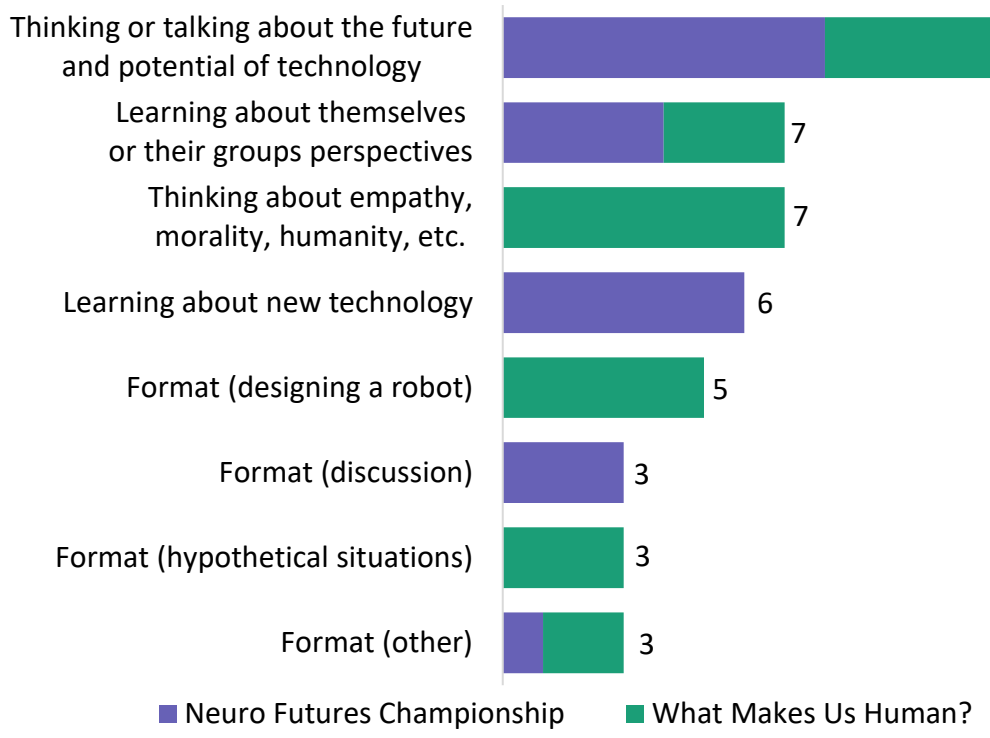
Overall, most visitors shared during the interview that they found the activities to be interesting and would try them again, and about a third thought they were interesting but would not try them again, see Figure 24. Some visitors offered suggestions for improving the games, with most suggestions for the "Neuro Futures Championship" game. For this game, nine groups indicated they would want to play again if they had new or different technologies to discuss. Three groups also had suggestions for new cards, either including currently available technologies that are comparable, with one visitor suggesting being able to compare contact lenses to bionic eyes, or to have a blank card that visitors could suggest a technology for. For "What Makes Us Human?" three groups offered suggestions for changes to the available attributes. One visitor wanted to remove "love," one wanted to add "free will," while another wanted to replace "creativity" with "imagination."

Figure 24. Responses to "How interesting did you find this activity?" (N=47 groups)



In follow-up questions for "Neuro Futures Championship" and "What Makes Us Human?" visitors elaborated on what they found interest or shared suggestions for improvement that would make them interested in trying the activity again, see Figure 25. For both activities, visitors found that thinking about or talking about the future or potential of technology (n=13) to be the most interesting aspects of the game, as one adult explained that the game "creates good discussion about the age we're going to live in, made me think about things I haven't before." They were also very interested in being able to learn about themselves through the discussion or learn more about the perspectives of people in their group (n=7), with the adults in one group explaining that they thought it was interesting to find out what the others in the group were thinking, while the teen in their group was interested to see when other agreed with her. Other aspects of the activities that visitors found interesting were unique to each game. For "Neuro Futures Championship," some visitors also found learning about new technology (n=6) to be interesting, while a few found the discussion format (n=3) to be most interesting. For "What Makes Us Human?" some visitors found thinking about empathy, morality, and humanity (n=7), designing a robot (n=5), or working through hypothetical situations (n=3) to be most interesting.

Figure 25. Responses to "What did you find most interesting?" (N=32 groups)[11]



5.3 Learning Objectives

While the primarily goal of the activities was to provide opportunities for visitors to practice behaviors related to personal attributes and interpersonal skills, the three broad engagement activities also shared the following **learning objectives**:

1) People's values determine which technologies are developed and used.
2) New technologies change society, sometimes in unexpected ways.
3) Scientists, engineers, and designers use their creativity to invent things and imagine the future, just like you do.
4) Brain research benefits from many perspectives, including yours.

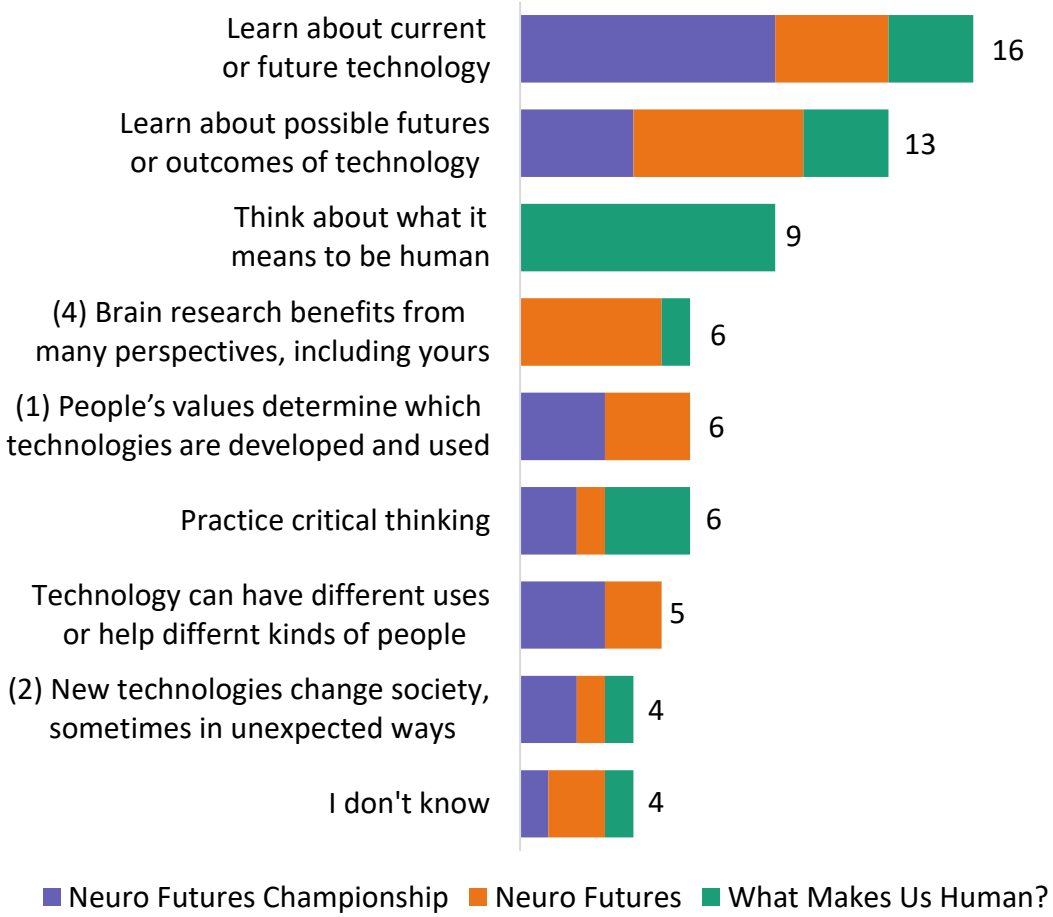
For all three activities, most visitors did not articulate ideas related to these goals when answering the question "What do you think the Science Center wants people to learn about in this activity?" Instead, many thought that they were supposed to learn about current or future technologies (n=16) or possible futures from the use of new technologies (n=13), particularly for the two "Neuro Futures" games, see Figure 26. For "What Makes Us Human?" visitors most commonly thought that they were supposed to learn about what it means to be human (n=9).

In terms of the intended learning objectives, visitors were more likely to recognize Objectives 1 (People's values determine which technologies are developed and used, n=6) and 4 (Brain research benefits from many perspectives, including yours, n=6) in the two "Neuro Futures" games, particularly around discussions related to the character cards. Only a few visitors (n=4) recognized Objective 2 (New technologies change society, sometimes in unexpected ways) as a

[11] Data missing for what visitors found interesting or what would make the activity more interesting for "Neuro Futures".

main takeaway. No visitors indicated that they recognize connections to Objective 3 (Scientists, engineers, and designers use their creativity to invent things and imagine the future, just like you do.) It is unclear from the observations to what degree the discussions included topics related to the learning objectives, and whether visitors would recognize those themes even if they did not identify them as major takeaways for the activities.

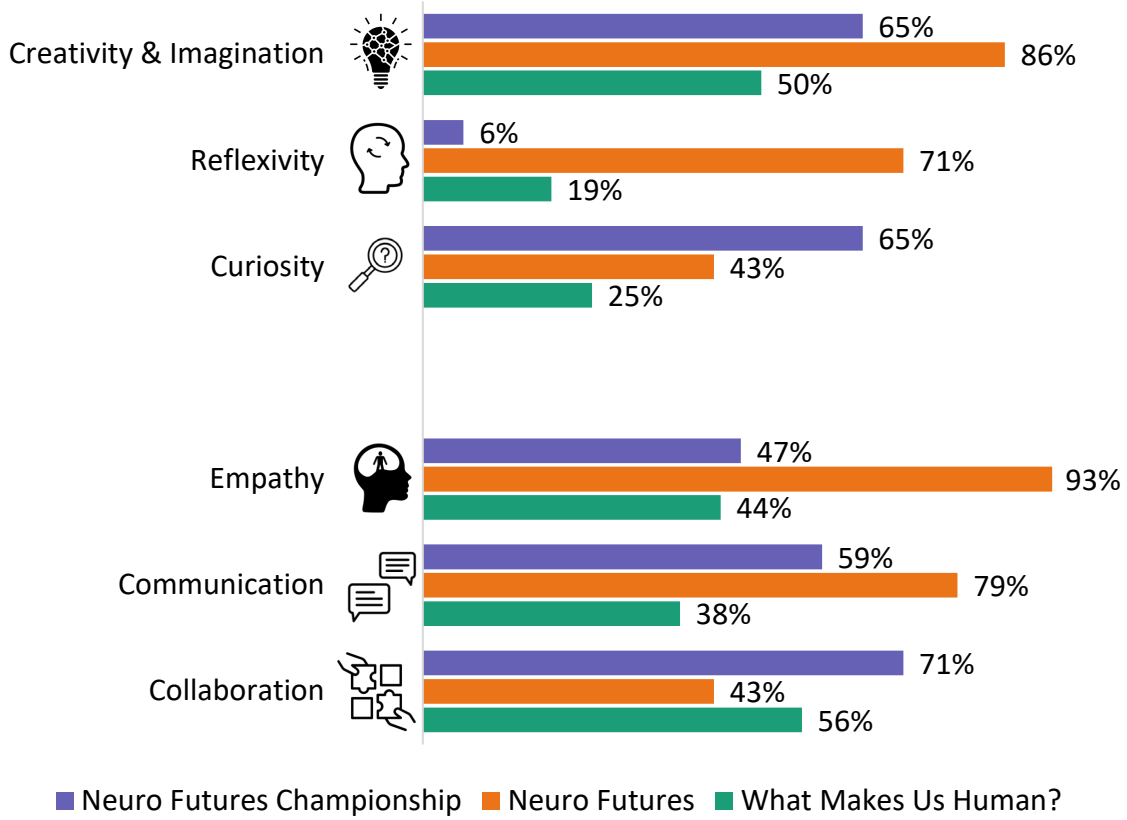
Figure 26. Responses to "What do you think the Science Center wants people to learn about in this activity?" (N=47 groups)



5.4 Personal attributes and interpersonal skills

The broad engagement activities appear to support opportunities to practice both personal attributes and interpersonal skills to varying degrees. "Neuro Futures Championship" and "What Makes us Human?" particularly supported practicing collaboration, and "Neuro Futures" supported practicing empathy. Figure 27 summarizes the prevalence of each behavior as it was observed within each activity, with more details broken down in the following sections.

Figure 27. Prevalence of observed interpersonal skills and personal attributes (N=47)

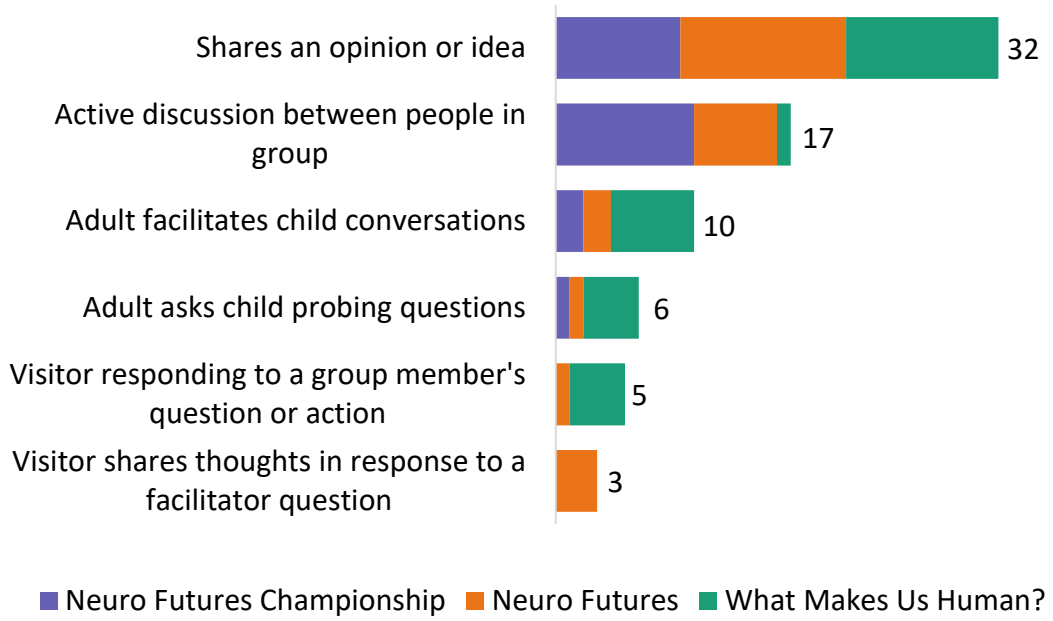


Evidence for these practices is most apparent in the observations, however when reflecting on what they were thinking about during different portions of the activities, visitors revealed ways that they were internally practicing those behaviors. Often these reflections indicated that visitors were thinking about how using the technology would work or be personally applicable. In some cases, these reflections highlighted evidence of practicing interpersonal skills or personal attributes and are included in the findings discussions below. A more in-depth study would be beneficial to understanding to what extent visitors may recognize that they are practicing these behaviors.

5.4.1 Visitors were able to practice interpersonal skills (communication, collaboration, and empathy) in all three broad engagement activities.

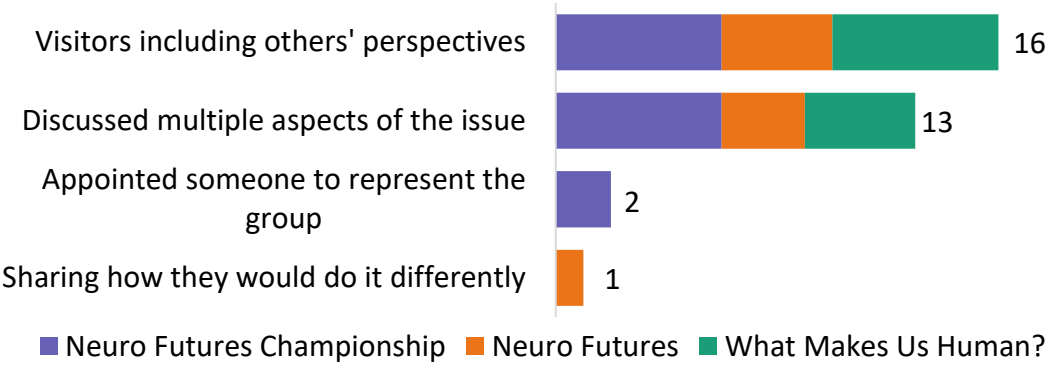
Communication was clearly observed in 27 of 47 groups. Focusing on effective communication with group members, this generally looked like active discussion between group members (n=16), and sometimes was a visitor responding to a group member's question or action (n=5) or responding to a facilitator's question (n=4), see Figure 28. Other behaviors that are probable evidence of communication were observed in 30 of 48 groups and generally involved a visitor sharing an opinion or idea (n=32). These were more one-sided comments from one visitor and may be evidence of communication but was unclear from the notes. Related to both communication and collaboration, some adults were observed facilitating conversations with their children, particularly in the "What Makes Us Human?" activity. This most often looked like adults asking children probing questions (n=6) or otherwise explaining or encouraging children to explain their thoughts (n=10).

Figure 28. Observed evidence of communication (N=47 groups)



Collaboration was observed in 27 of 48 groups. Across the three activities, the main forms of collaboration observed included visitors including other group members perspective, through taking turns or agreeing (n=15) and discussing multiple aspects of either technology or attribute cards (n=13). Possible collaboration was observed in 3 of 48 groups. Behaviors were observed that could be evidence of collaboration, or could lead to collaboration, included a group appointing someone as a tiebreaker (n=2) or a visitor sharing how they would have made difference choices (n=1). Evidence of collaboration was similarly present across all three activities, see Figure 29

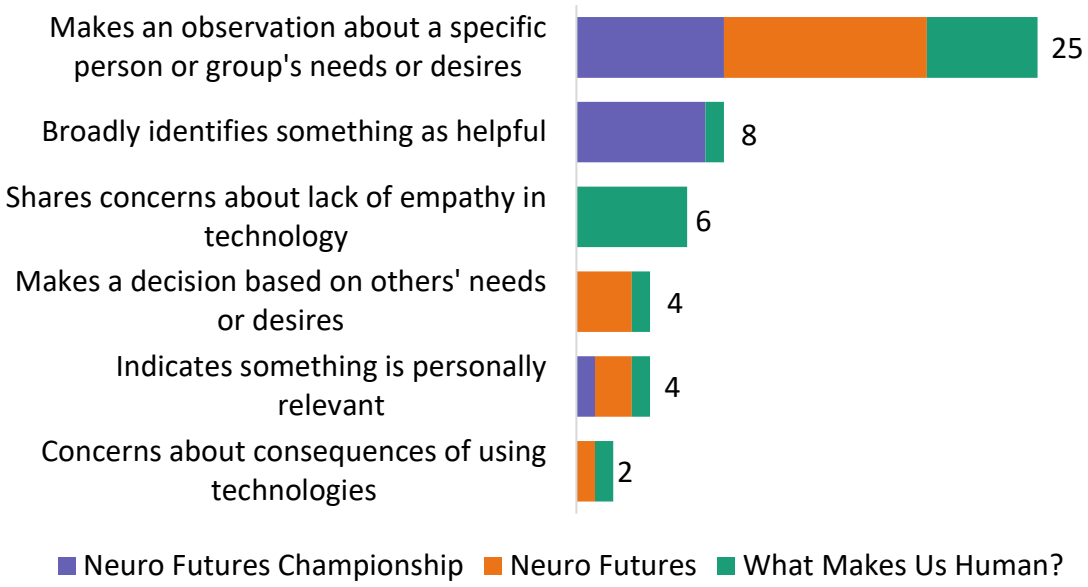
Figure 29. Observed evidence of collaboration (N=47 groups)



Empathy was observed in 28 of 47 groups. In most cases, this was the group making observations about a specific person or group's needs or desires (n=25) and sometimes they would articulate that they were making a decision based on someone else's needs or desires (n=4), see Figure 30. Possible empathy was observed in 18 of 48 groups. Some visitors broadly identified something as helpful (n=8), though it is unclear what made something helpful, most commonly in the "Neuro Futures Championship" game, while a couple

had concerns about the consequences of technology (n=2). In both situations, it is unclear from the observation notes whether they are empathizing with someone else or thinking from their own perspectives. Some visitors were concerned about possible lack of empathy in technology, particularly in "What Makes Us Human?" (n=6), and a few participants saw personal relevance in the technology (n=4). When reflecting on the activity, some visitors indicated that they were empathizing with others when exploring the technology or ability cards, sharing that they were considering how the technologies would benefit others.

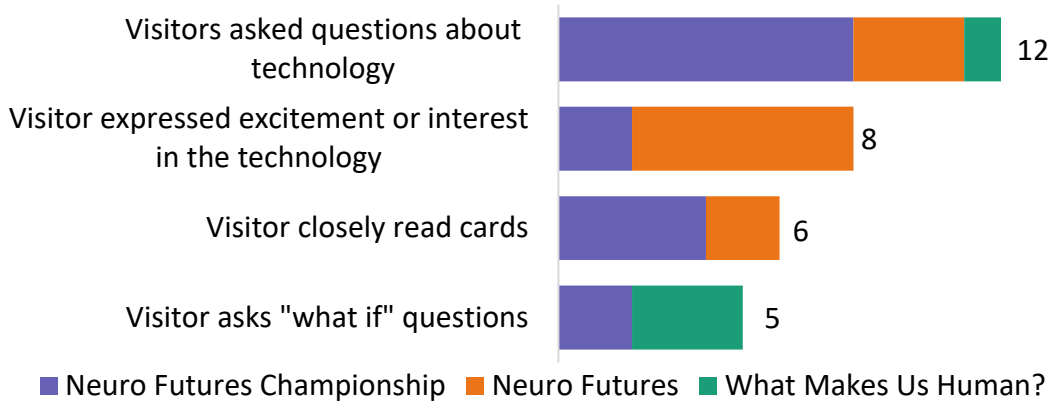
Figure 30. Observed evidence of empathy (N=47 groups)



5.4.2 *Visitors showed clear evidence of curiosity or creativity and imagination, and to a lesser extent indicated possible reflexivity when interacting with the broad engagement activities.*

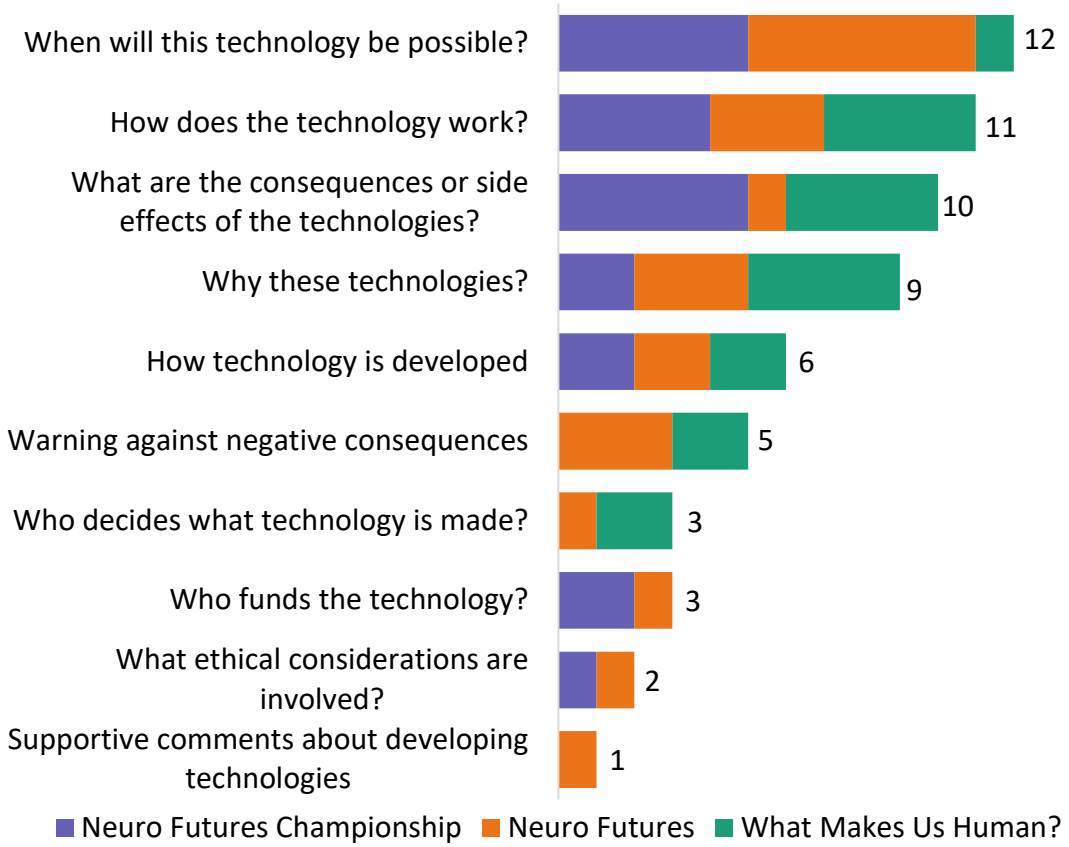
Curiosity was observed in 21 of 47 groups. This was most often observed in the "Neuro Futures Championship" game, but was present in the other activities, see Figure 31. Most often, this was observed through visitors wanting to learn more about technology, either asking questions about the technology, like how it worked (n=12), or closely reading the cards to get as much information as they could (n=5) or asking hypothetical "what if" questions (n=5). Possible curiosity was observed in 7 of 47 groups, when visitors expressed excitement or interest in the technology (n=7).

Figure 31. Observed evidence of curiosity (N=47 groups)



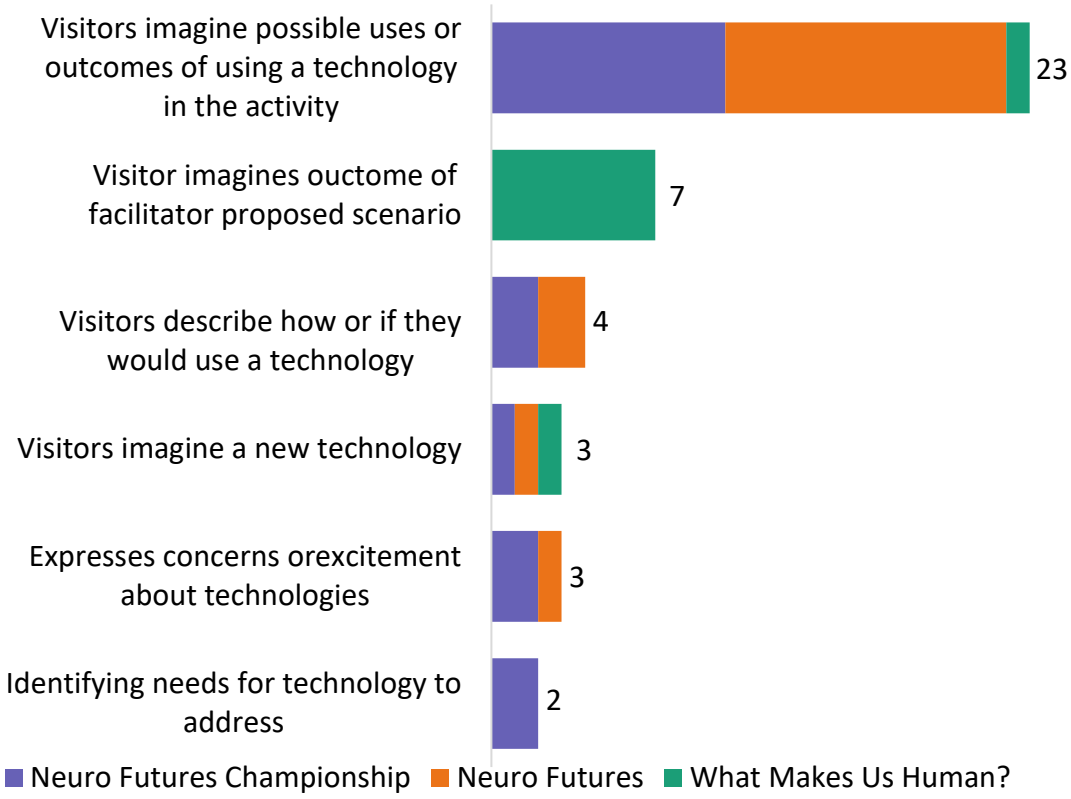
An interview question asked visitors what, if anything, they would want to tell or ask a scientist working in the field. Almost all groups (n=45) had questions or comments for scientists, and many groups had multiple questions, indicating that these activities sparked curiosity, see Figure 32. Most commonly, visitors asked questions about when the technology will be possible (n=12), how the technologies work (n=11), and what are the possible consequences (n=10). Other areas of interest included how technology is developed (n=3), who decides which technologies are made (n=3), and who funds the technology (n=3).

Figure 32. Responses to "After doing this activity, what, if anything, would you want to tell or ask a scientist or engineer working in this field?" (n=45 groups)



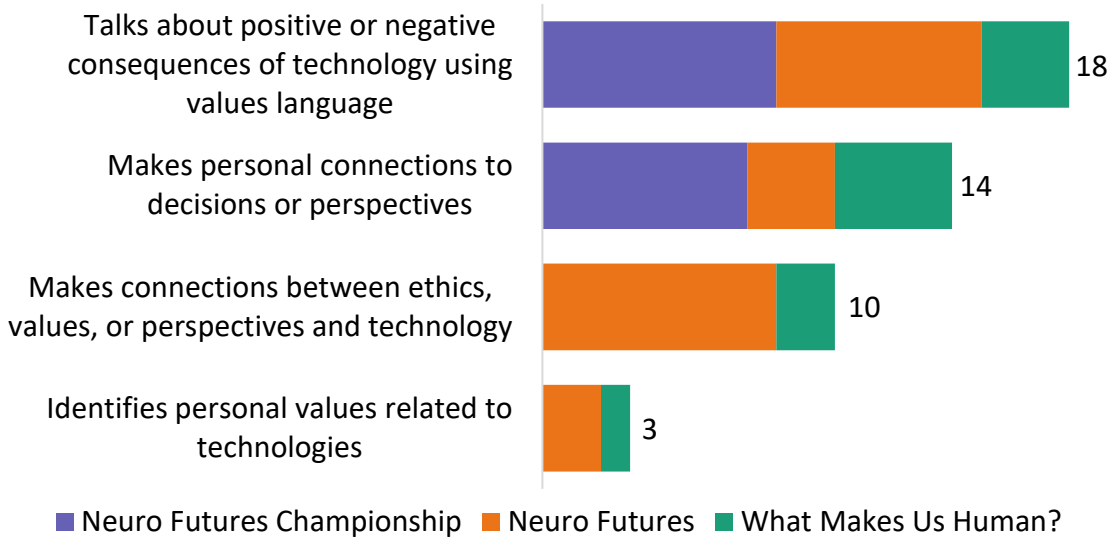
Creativity and imagination were observed in 30 of 47 groups. This looked different in each of the games, with the most overlap between the two "Neuro Futures" games, see Figure 33. In these games, the focus was on exploring technology, and visitors were often observed imagining possible applications or outcomes of one of those technologies, beyond what was described on the cards (n=22) and a few visitors suggested a new technology (n=2). In these games there were also behaviors that possible indicators of creativity or would lead towards creative thinking, including talking about if they would use the technology (n=4), expressing concerns or excitement (n=3), or identifying needs that technology could address (n=2). In the "What Makes Us Human?" game, there were fewer instances of observed creativity, all of these (n=7) were the visitor imagining a possible outcome for a scenario the facilitator proposed, beyond what was described on the cards. When reflecting on the activity, some visitors elaborated on the ways that they were practicing creativity by imagining possible outcomes or technologies, including benefits, consequences, or limitations.

Figure 33. Observed evidence of creativity and imagination (N=47 groups)



Reflexivity was observed in 12 of 47 groups, see Figure 34. It should be noted that this process is often internal and therefore difficult to observe without leading prompts. When reflexivity was observed, visitors were making connections between someone's values or perspectives and technology (n=9) or identifying that their own values related to the technologies (n=1). Possible examples of reflexivity were present in 24 of 48 groups, where the degree that the visitor was making the connection was unclear. These examples included visitors talking about positive or negative consequences of technology or decisions using value-laden language (n=17) and making personal connections to their decisions or perspectives (n=14).

Figure 34. Observed evidence of reflexivity (N=47 groups)



6. Conclusion

The formative evaluation for the Changing Brains project addressed how the broad engagement and deep engagement experiences could be improved to meet the project goals around learning objectives and outcomes, as identified in the logic model above. In addition, the evaluation addressed experience-specific goals around learning, engagement, or usability, as needed. Overall, the study was primarily intended to provide feedback for developers to:

- understand how participants interacted with the activities, in order to inform changes or improvements;
- learn to what extent participants are meeting learning objectives; and
- uncover interesting questions for future investigation.

Evaluation for the Brain Enhancement Conversation Lab consisted of a survey directly after the event. The survey focused on participants' overall impressions of the event; opportunities to practice the personal attributes important for neuroethics engagement (curiosity, creativity, reflexivity, communication, collaboration, and empathy); and their awareness of neuroethical issues and questions.

Formative evaluation was completed for the three broad engagement experiences (Neuro Futures, Neuroethics Championship, and What Makes Us Human?) once they were in their final stage of development. Visitors were observed using the activities and invited to participate in a short interview. Observations focused on interpersonal skills and personal attributes. In addition to general feedback, interviews focused on interest in the activities, success of learning objectives, reflecting on game elements.

6.1 Conversation Lab Findings

Overall, participants reported positive impressions about the conversation lab, indicating that it was a welcoming and comfortable event. They valued the variety of perspectives included in the event, the discussion format, and learning new or useful information. Most participants agreed they were able to practice collaboration and communication at the event, through working with others to think about the ethics of brain stimulation and sharing their perspectives. Many participants strongly agreed that they were able to practice creativity and reflexivity through reflecting on their values and imagining possible futures. They also reported increased self-efficacy and awareness around neuroscience topics.

6.2 Broad Engagement Activity Findings

Overall, the three activities (Neuro Futures, Neuroethics Championship, and What Makes Us Human?) worked well for most visitors, with minimal usability issues observed or reported. Some groups showed evidence of confusion, however in all cases, facilitators were able to clarify in the moment to not detract from the experience. Most visitors shared during the interview that they found the activities to be interesting and would try them again. For "Neuro Futures Championship" and "What Makes Us Human?" visitors elaborated that thinking about or talking about the future or potential of technology to be the most interesting aspects of the game.

During the interview many participants thought the activities were opportunities to learn about current or future technologies or possible futures from the use of new technologies. Visitors were less likely to describe what they were supposed to learn in terms that overlapped with the learning objectives. It is unclear from the observations to what degree the discussions included

topics related to the learning objectives, and whether visitors would recognize those themes even if they did not identify them as major takeaways for the activities.

The primary goal of the activities was to provide opportunities for visitors to practice behaviors related to personal attributes and interpersonal skills. Each activity appeared to support each of the behaviors to varying degrees. “Neuro Futures Championship” and “What Makes us Human?” particularly supported practicing collaboration, and “Neuro Futures” supported practicing empathy. Visitors were able to practice interpersonal skills (communication, collaboration, and empathy) in all three activities. Visitors showed clear evidence of curiosity or creativity and imagination, and to a lesser extent indicated possible reflexivity when interacting with the broad engagement activities.

Evidence for these practices is most apparent in the observations, however when reflecting on what they were thinking about during different portions of the activities, visitors revealed ways that they were internally practicing those behaviors. A more in-depth study would be beneficial to understanding to what extent visitors may recognize that they are practicing these behaviors.

6.3 Emergent findings

Observation data provided preliminary evidence that specific design strategies may support visitors’ practicing the behaviors related to personal attributes or interpersonal skills. These connections were drawn from facilitator reflections, as well as visitor observations, and suggest strategies that can be leveraged to influence participant outcomes. A more in-depth study would be beneficial, in order to draw clearer connections between design strategies and participant behaviors.

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Appendix A: Brain Enhancement Conversation Lab Survey

Science MATTERS: Conversation Lab - Brain Enhancement Survey

*The purpose of this survey is to evaluate effectiveness of the Conversation Lab and learn about your experiences exploring the ethics of brain stimulation. Results will be used to inform our current and future programs. Participation is **voluntary**, and your responses will be **anonymous**.*
*You must be **18 or older** to complete the survey. Thank you for your feedback!*

1) Please rate your agreement with the following statements: (select one response for each statement)

	Strongly disagree	Disagree	Agree	Strongly agree
Overall, I enjoyed this event.	☐	☐	☐	☐
I felt welcomed at this event.	☐	☐	☐	☐
I felt comfortable sharing my views during table discussions.	☐	☐	☐	☐
Different views were respected during table discussions.	☐	☐	☐	☐
The museum is a safe space to gather and discuss the societal impacts of science.	☐	☐	☐	☐
The speakers and information prepared me to discuss the ethics of brain stimulation at my table.	☐	☐	☐	☐
Information was trustworthy & balanced.	☐	☐	☐	☐

2) What did you value about this event?

3) **Please rate your agreement with the following statements:** (select one response for each statement)

	Strongly disagree	Disagree	Agree	Strongly agree
This event inspired me to want to learn more about the ethics of brain stimulation.	☐	☐	☐	☐
I imagined possible futures of brain stimulation for me and/or others.	☐	☐	☐	☐
I was able to reflect on how my values impact my decisions.	☐	☐	☐	☐
I heard perspectives different from my own.	☐	☐	☐	☐
I heard perspectives similar to my own.	☐	☐	☐	☐
Working with others helped me think about the ethics of brain stimulation.	☐	☐	☐	☐
I was able to share my thoughts about the ethics of brain stimulation.	☐	☐	☐	☐

4) **How much did this event increase your awareness or understanding of the following:** (select one response for each statement)

	Not at all	A little	Somewhat	A great deal
New research or technology related to brain stimulation.	☐	☐	☐	☐
Ethical issues or concerns about brain stimulation.	☐	☐	☐	☐

How much did this event increase your confidence in your abilities to do the following: (Please select one response for each statement)

	Not at all	A little	Somewhat	A great deal
Learn more about the ethics of brain stimulation.	☐	☐	☐	☐
Share my views about the ethics of brain stimulation with friends and family.	☐	☐	☐	☐
Discuss different views on the ethics of brain stimulation with others.	☐	☐	☐	☐

5) What, if anything, would you change about this event?

6) Choose the category that best describes you

- Community member
- Scientist / researcher in a brain science-related field
- Undergraduate / graduate student in a brain science-related field
- Other:_____

7) What is your age? _____

8) What is your gender?

- ☐ Man
- ☐ Woman
- ☐ Non-binary
- ☐ Prefer to self-describe:_____
- ☐ Prefer not to answer

9) With which racial or ethnic group(s) do you identify?

- ☐ American Indian or Alaskan Native
- ☐ Asian or Asian American
- ☐ Black or African American
- ☐ Hispanic or Latino/a/x
- ☐ Native Hawaiian or Pacific Islander
- ☐ White
- ☐ Prefer to self-describe:_____
- ☐ Prefer not to answer

10) What is your highest level of education completed?

- ☐ Some high school
- ☐ High school degree or equivalent
- ☐ Some college
- ☐ College degree
- ☐ Some graduate work
- ☐ Graduate degree
- ☐ Other:_____
- ☐ Prefer not to answer

Thank you!

Appendix B: Broad Engagement Activity Instruments

Changing Brains Observation

Group Composition	Please indicate in the notes who is speaking (Adult = A, Teen = T, or Child = C)	
# Adults:	**# Teens (ages 12-17):**	**# Children (ages 0-11):**

Observation notes Check box whether present or not. Include example quotes or descriptions of behaviors. Note when behavior is prompted by the facilitator.	
 **Usability or accessibility issue** **Y** ❒ **N** ❒	 **Confusion** (vocabulary, what needs explanation) **Y** ❒ **N** ❒
 **Creativity & Imagination** (creates solutions, imagines scenarios, suggests uses for tech) **Y** ❒ **N** ❒	 **Collaboration** (considers other perspectives to make a decision, consensus building) **Y** ❒ **N** ❒
 **Curiosity** (asks questions related to activity content, prolonged engagement) **Y** ❒ **N** ❒	 **Communication** (productive communication - shares ideas, active listening, responds to ideas/suggestions etc.) **Y** ❒ **N** ❒
 **Reflexivity** (talks about connections between values and technologies, recognizes impacts of biases and personal experiences) **Y** ❒ **N** ❒	 **Empathy** (talks about/represents another person's perspective, talks about how someone else's values are similar or different from their own) **Y** ❒ **N** ❒

Additional notes:

Changing Brains Interview

Hi, my name is _____. The Science Center is trying to learn about the activity you just tried, and we would like to know what you think about it. Would you be willing to answer some questions about your experience?

- *[If yes]: Great! This should take less than 5 minutes. Everything you say will be anonymous and you can stop at any time or choose not to answer any questions.*
- *[If yes **and** <18 also ask adults]: Are you the parent(s) or guardian(s)? Is it okay if we ask your child(ren) some questions about their experience?*
- *[If no]: Thank you! Have a great day!*

1. How interesting did you find this activity? (show visitor scale on back of clipboard and circle answer)

- So interesting I would try it again
- I was interested, but would not try it again
- A little interesting
- Not at all interesting

Follow up: Probe What did you find most interesting? [or] What would have made it more interesting?

2. What do you think the Science Center wants people to <u>learn</u> about in this activity?
[Probe visitor if answer is unclear: e.g. Can you tell me more about that?]

3. After doing this activity, what, if anything, would you want to tell or ask a scientist working in this field?

4. What were you thinking about in Round 1 when you were exploring the [technology / ability] cards?
Probe: How, if at all, did the activity help you think about that?

Probe (optional, pick 1 area): I noticed you [describe notable moment of creativity / curiosity / collaboration / communication / reflexivity / empathy], what were you thinking about when you said/did that?

5. What were you thinking about in Round 2 while you were [playing another character / creating a robot]? Probe: How, if at all, did the activity help you think about that?

Probe (optional, pick 1 area): I noticed you [describe notable moment of creativity / curiosity / collaboration / communication / reflexivity / empathy], what were you thinking about when you said/did that?

6. Is there anything else you would like to add? (including any points of confusion)

7. What are the ages and genders of the people in your group?

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Age										
Gender										