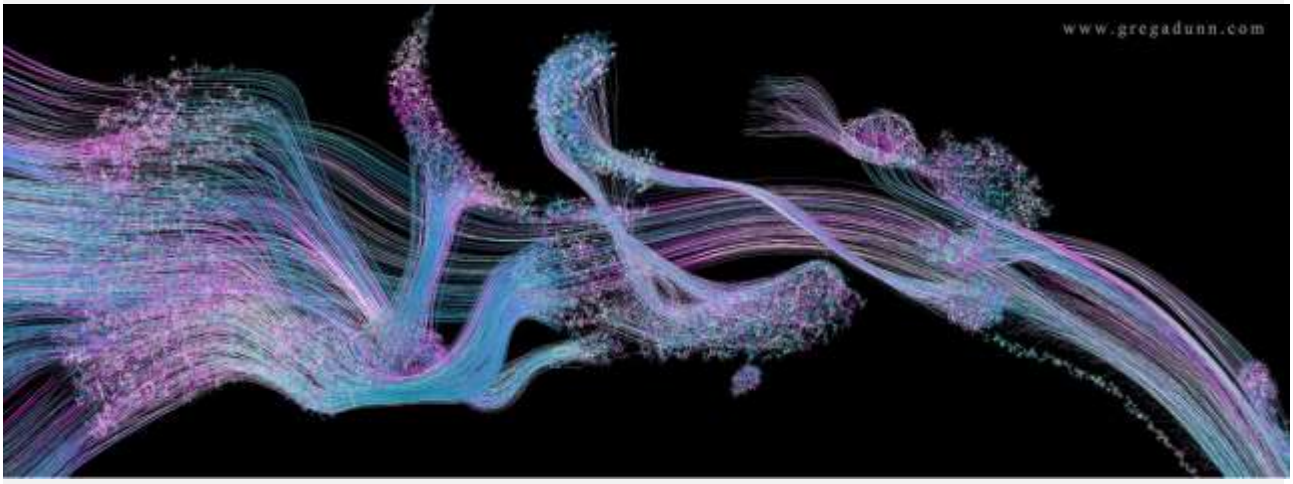
Self Reflected

Summative Evaluation



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EXECUTIVE SUMMARY

Merging art and science, *Self Reflected* aims to communicate the incredible complexity of the neural signaling in our brains that makes us who we are. The artists, Dr. Greg Dunn and Dr. Brian Edwards, invented a novel technique called reflective microetching to simulate the microscopic behavior of neurons in the viewer's brain as they observe this work of art. *Self Reflected* is currently on display in the *Your Brain* exhibit at The Franklin Institute in Philadelphia. This summative evaluation study explores museum visitors' behavior, reactions, and learning outcomes as they interact with *Self Reflected* to determine how this unique work fits into the landscape of an interactive science museum as well as its cognitive and affective impact.

Key findings include:

- *Self Reflected* clearly conveys the artists' core message; 85% of visitors understand the artists' intention for viewers to appreciate the function and complexity of the human brain.

- Visitors find *Self Reflected* very compelling, giving it a median rating of 5 on a 5-point scale, with a mean of 4.75. Upon first seeing the piece, 78% of visitors have an *enthusiastic* or *positive* reaction.

- *Self Reflected* quickly gets its message across, while offering more engaged visitors the opportunity to linger and reflect. It has a capture rate of 68% and a mean dwell time of 39 seconds among casual visitors, ranging from 2-180 seconds. This is comparable to other artistic installations of similar scope at The Franklin Institute.

- *Self Reflected* has strong attracting power, ranking sixth among all 71 exhibit experiences in *Your Brain.* It ranks 37 of 71 in holding power—lower than challenge-based games and devices allowing open-ended play, but higher than interactive graphics, videos, and other artifacts.

- Visitors physically interact with *Self Reflected*; 63% of free-choice visitors view the work from at least two different locations.

- The primary impact of *Self Reflected* is affective rather than cognitive, but science learning is significantly correlated with level of prior knowledge about the brain. Interaction with the supporting video and content panel also deepens the cognitive outcomes of *Self Reflected*.

- Visitors make personal emotional connections*;* 53% of free-choice visitors and 97% of recruited visitors express that viewing *Self Reflected* affected their perception of their own brain.

- The techniques used to create *Self Reflected* are novel to visitors; 85% of visitors learn something about the artistic process—most commonly, microetching—through their interaction.

- After viewing *Self Reflected*, visitors appreciate the power of art to broaden modes of learning science, increase the accessibility of science, and help visualize the unseen.

INTRODUCTION

Self Reflected is the most detailed artistic depiction of the brain ever realized, created by Dr. Greg Dunn, an artist and neuroscientist, and Dr. Brian Edwards, an artist and applied physicist. Through the work, the artists aim to communicate the enormous complexity of the brain and elicit a sense of awe by bridging the macroscopic perception of the brain as a wrinkled, mysterious, three-pound organ and the microscopic behavior of neurons. *Self Reflected* shows the movement and dynamic communication of information as the brain is visually stimulated by a work of art—the brain perceiving itself.

In 2016, *Self Reflected* was installed for long-term display in *Your Brain*, an 8,500 sq. ft. exhibition at The Franklin Institute in Philadelphia, PA. In determining the efficacy of *Self Reflected* as a science exhibit, the artists wished to explore the following questions:

- Does *Self Reflected* successfully convey the immense complexity of the brain?
- How does the attracting and holding power of *Self Reflected* compare to other exhibit styles?
- Can *Self Reflected*, as a two-dimensional display, encourage physical movement and interaction?
- Do viewers experience an emotional response that changes their perspective on the brain as a whole?

BACKGROUND

To create this work of art, Dunn and Edwards invented the technique of reflective microetching to manipulate the reflectivity of a surface microscopically. This technique captures a third dimension of information that can be used to create animations in a seemingly two-dimensional surface. The technique combines a complex array of hand drawing, scientific data, computer simulation, photolithography, gilding, and strategic lighting design.

The image in the 134” x 94” artwork represents one very thin slice of a human brain, 22 times larger than life. Encompassing over 500,000 neurons, the image is based on an oblique sagittal slice (angled from right to left) through the brain. As the overhead light moves from left to right, observers see motion through various functional regions of the brain. The movement of light illuminates the patterns created by the firing of electrical signals in the brain over 500 microseconds of time.

Housed in the Frank Baldino, Jr. Gallery of the Nicholas and Athena Karabots Pavilion at The Franklin Institute, the *Your Brain* exhibition uses a hands-on, interactive approach to educating museum visitors about the science of the human brain from a personal point of view. Divided into a series of smaller galleries, *Your Brain* guides visitors from the cellular level of neurons through the connections between functional brain regions to the higher cognitive processes that interpret the world around us.

Within the *Your Brain* exhibit, *Self Reflected* is displayed in the Neurons gallery, accompanied by interactive devices exploring how neurons connect to each other, the speed of neural signaling, and the electrical and

chemical nature of neural communication, as well as a multimedia display of neuroimaging data contributed by research scientists. The preceding galleries of the exhibit address common misconceptions about the brain, display real specimens of the human brain and squid neurons, and immerse visitors in an 18-foot-tall climbing structure with lighting and sound effects designed to evoke the complex, dynamic environment of the brain. *Self Reflected* comes into view as visitors exit the second gallery featuring the "Neural Light Show" climbing structure (Fig. 1).

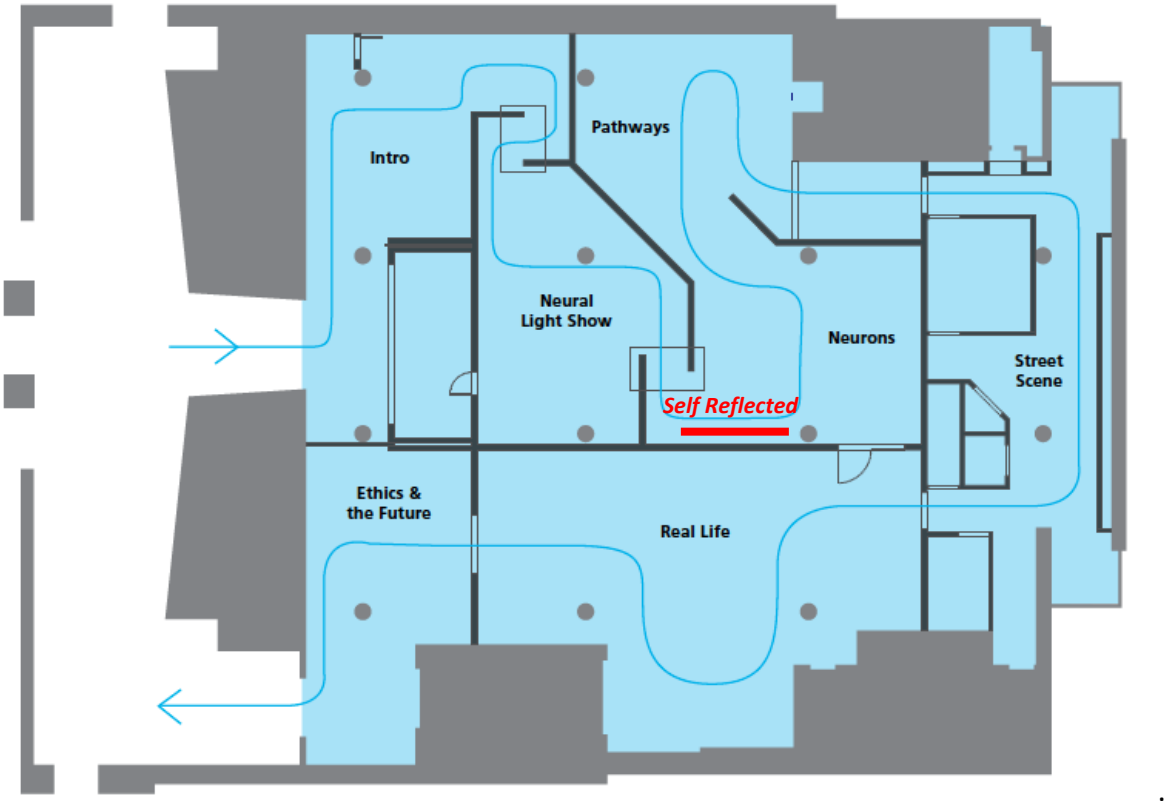

Figure 1. Floor plan of the *Your Brain* exhibit showing the location of *Self Reflected.*

In addition to the artwork, there are several interpretive components to the *Self Reflected* display (Fig. 2). To its left, a short text panel mounted to the neighboring column briefly describes the work, along with a small monitor playing on demand a 2-minute video with additional information about the artists, the production, and the neuroscience content depicted in the piece. The graphics and a transcript of the video are included in Appendix A. A small label to the right of the artwork identifies the title, artists, size, and medium. In front of the artwork is a multitouch table-based interactive device called "Build a Network." The artists suggest in the video that the "sweet spot" for viewing the artwork is to stand behind this table.

Figure 2.
Components of the *Self Reflected* display.
A) Interpretive text panel.
B) Short video. C) Artwork.
D) Label. E) "Build a Network" interactive device. The "sweet spot" for viewing *Self Reflected* is behind this table (i.e. in the foreground of this photo).

METHODS

Three datasets were collected and analyzed through a mixed-methods approach to determine 1) how *Self Reflected* compares with other museum exhibits, 2) how free-choice visitors interact with *Self Reflected,* and 3) how randomly recruited visitors interact, as well as the impact of their prior knowledge. Data were collected between February and July 2017 with groups of adults and children visiting The Franklin Institute. All survey and interview instruments are included in Appendix B.

Attracting and Holding Power. Visitors were tracked and timed as they entered the Neurons gallery until they moved into the next gallery (Pathways). As a visitor group exited the Neural Light Show, one member of the group was randomly selected for observation. The time (in seconds) that they spent interacting with the *Self Reflected* display and whether or not they took a photograph or video were recorded, along with the composition of their entire group. Sixty visitors were tracked in this phase of evaluation.

Outcomes of Free-choice Interactions. Visitor groups were included in this phase of evaluation if they demonstrated sustained, free-choice interest in *Self Reflected* by pausing to observe it for more than 30 seconds. Behavioral observations were recorded while the visitor grouping viewed the piece. Once the small group completed their interaction and moved away, they were approached and asked to contribute their feedback for the evaluation study. Upon consent, they participated in a short interview. Forty groups, including fifty-two adults and ten children, were surveyed.

Outcomes of Recruited Interactions. Adult visitors were randomly intercepted as they exited the Neural Light Show gallery and invited to participate in this phase of evaluation. Upon consent, they were asked if

they had previously been to the *Your Brain* exhibit, and whether they had ever seen *Self Reflected*. Those who had already seen *Self Reflected* were thanked and excused from further participation. All others continued by filling out a pre-experience survey with their demographic information and self-selected ratings of their prior knowledge about the brain and their prior experience with art.

Following completion of the survey, participants were first asked to observe *Self Reflected* and express their initial reaction to the piece. They were then informed about the different components of the display, but not specifically instructed on how to interact. Once they finished their self-directed exploration, they participated in a short interview. Forty adult visitors were surveyed.

Data Analysis. Coding schemes were created to classify answers to open-ended questions into representative categories. Two data collectors then coded the answers independently to ensure interrater reliability. Pearson's chi-square analyses were conducted to determine whether frequencies of answers were statistically different between typical behaviors or prior levels of knowledge to identify correlations with reactions and learning outcomes.

RESULTS: ATTRACTING AND HOLDING POWER

Visitor tracking shows that *Self Reflected* has a capture rate of 68%. The attracting power of any particular element in an exhibition depends on a number of factors, including visibility, time of encounter in an exhibition (elements closer to the beginning tend to capture more visitors), and number of competing elements in the same vicinity. Among the 71 exhibit experiences across all galleries in *Your Brain*—including interactive devices, artifacts, and videos—*Self Reflected* is ranked sixth, demonstrating its strong attracting power in the exhibition. The five experiences with a higher capture rate include the Neural Light Show, the centerpiece of the exhibition, and four interactive experiences in the Intro gallery whose high attracting power is likely enhanced by their early encounter location. *Self Reflected* has the highest capture rate of the five experiences in the Neurons gallery where it is displayed.

The average dwell time is 39 seconds, ranging from a minimum of two seconds to a maximum of three minutes. Of those who interact with *Self Reflected*, their interactions can be categorized into three levels based on dwell time and characteristics of their behavior: *curious*, *interested*, and *engaged* (Table 1). Eight visitors (20%) photographed the artwork (either the artwork alone or including themselves or a group member). Of these, 88% fall into the category of *engaged* visitors.

Category	Dwell time	Typical Behavior	Percent of visitors
Curious	<15 s	Visitors notice the artwork as they enter the gallery, approach it briefly, and then move on to other exhibit elements.	39%
Interested	15-40 s	Visitors approach the artwork, casually look at it from different angles, and/or read some or all of the text panel.	27%
Engaged	>40 s	Visitors intentionally look at the artwork from different angles, read some or all of the text panel, and/or watch some or all of the video. They may return to the artwork more than once while their group is in the gallery, and are most likely to photograph the artwork.	34%

Table 1. Classification of visitor interactions with *Self Reflected* based on dwell time and characteristic behaviors.

There is a trend (though not significant, p=0.07) between group composition and dwell time. Groups with children, pooled from tracked visitors identified either as children or adults accompanied by children, have a lower dwell time than groups with adults only (Fig. 3). However, in multiple cases, adults accompanied by children were observed interacting with *Self Reflected* while their children played at the "Build a Network" table, suggesting the opportunistic pairing of these two experiences is beneficial for intergenerational groups.

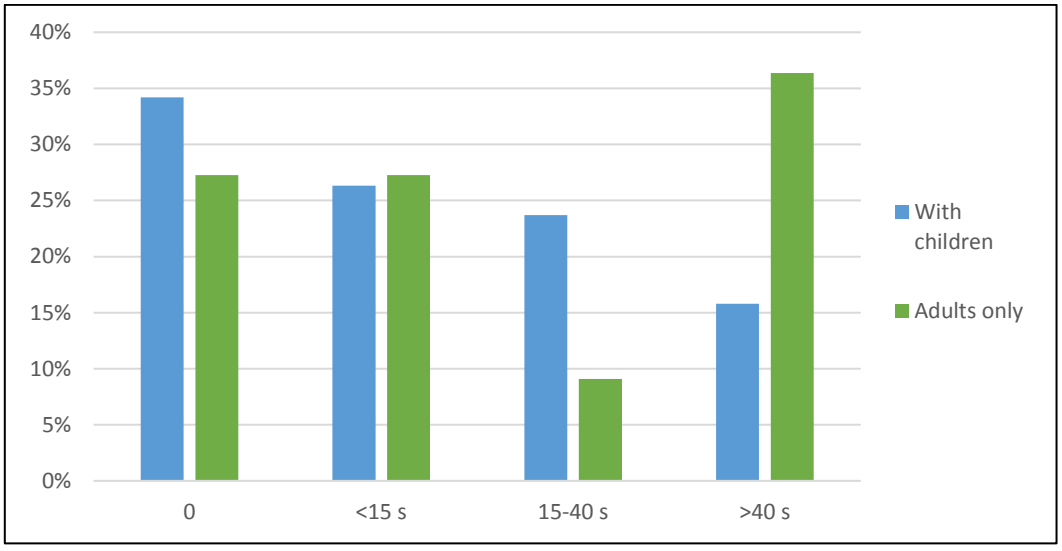

Figure 3. Differences in dwell time between visitor groups with and without children.

To assess the relative attracting and holding power of *Self Reflected*, the capture rate and dwell time was compared to timing and tracking data for other exhibits at The Franklin Institute. The comparison data are drawn from each exhibition's original summative evaluation, conducted shortly after it opened to the public. Four artistic installations at the museum are of similar scope as *Self Reflected*—each a unique focal point within its respective exhibit and intended to inspire a primarily emotional response. Among this group, *Self Reflected* ranks second in capture rate (Table 2). Its mean dwell time is the lowest, but roughly similar in range to most of the others; *Newton's Dream* is an outlier because it has an obvious sequence of events that many visitors enjoy watching from beginning to end.

Artifact/Exhibition	Description	Capture rate	Range of dwell time (s)	Mean dwell time (s)
Electrical Signals Wall *Electricity*	Art installation of sensors and lights that visualize waves of radiation emitted by visitors' cell phones	75%	5-188	62
Self Reflected *Your Brain*	Microetched image of the brain that simulates neural activity through reflection and movement of light	68%	2-180	39
Machine Icon *Amazing Machine*	Kinetic sculpture that communicates the fluidity of mechanical motion created with simple components	65%	10-254	59
Newton's Dream *Sir Isaac's Loft*	Kinetic sculpture that shows transfer of energy as balls travel along tracks to power a playful series of events	48%	4-1090	129
Maillardet's Automaton *Amazing Machine*	18th century humanoid machine with intricate internal mechanisms that control its ability to write and draw	23%	3-223	47

Table 2. Capture rate and dwell time of selected artistic and artifact installations at The Franklin Institute.

The holding power of *Self Reflected* was also compared to other exhibit components in *Your Brain* with different styles of interaction. While the capture rate of *Self Reflected* was very strong, as described previously, the mean dwell time of *Self Reflected* ranked 37 out of 71 exhibit experiences across all galleries in the exhibition. A representative selection of exhibit experiences is listed in Table 3 to illustrate the range of styles and their holding power. Interactive games that pose an explicit challenge to visitors are among those that have the highest dwell time, depending on the length of the game, followed by those that allow open-ended play. Interactive videos and graphics generally have lower dwell times. Art and artifacts seem to vary in dwell time based on their complexity—for example, a plastinated specimen or a 3D printed brain scan appears relatively straightforward to observe and process, while a piece with the detail and aesthetic beauty of *Self Reflected* or the high personal relevance of *No Two Brains Are Alike* elicits greater reflection and conversation.

Artifact/Exhibit	Description	Capture rate	Range of dwell time (s)	Mean dwell time (s)
Lie to Me (game)	Visitors explore involuntary facial cues through video recording and slow motion playback as they tell a lie	40%	3-685	164
Test Your Memory (game)	Visitors are challenged to remember increasingly longer strings of numbers	38%	11-579	152
Build a Network (open-ended)	Visitors connect digital neurons on a multitouch table to create simple networks	42%	6-286	88
No Two Brains Are Alike (art)	A collection of artists' interpretations of their own brains to highlight the uniqueness of individual people	76%	3-355	53
Test Your Sensitivity (open-ended)	Visitors test the number of touch receptor nerve cells in different parts of their body	52%	7-85	42
Read the Faces (game)	Visitors try to match images of different people expressing the same emotion	30%	3-129	41
Self Reflected (art)	Microetched image of the brain that simulates neural activity through reflection and movement of light	68%	2-180	39
Scan a Brain (interactive video)	Visitors slide a mock scanner across a head to explore MRI images showing internal brain anatomy	52%	5-170	39
Laundromat Illusions (interactive graphics)	Visitors observe visual illusions to see how the brain processes conflicting sensory information.	34%	3-77	26
See a Real Brain (artifact)	Display of a plastinated human brain and spinal cord	72%	2-96	22
Diffusion MRI Icon (art)	A 3D-printed sculpture displaying the connected neural pathways in a brain	52%	3-94	21

Table 3. Capture rate and dwell time of selected interactive devices in *Your Brain* at The Franklin Institute.

RESULTS: OUTCOMES OF CASUAL ENGAGEMENT

The focus of this phase of evaluation was to understand in greater depth the behaviors and outcomes of *interested* and *engaged* visitor groups (as classified in Table 1). For this study, a group was defined as the immediate set of people interacting with *Self Reflected;* it did not include other members of the same social group who may have been elsewhere in the gallery. Over half the visitors observed (58%) interacted with *Self Reflected* individually.

Of the forty groups observed, eight groups (20%) included a child between ages 4 and 16. Children comprised only 16% of the observed free-choice visitors, compared to 32% of the Institute's overall visitor profile (as recorded in a 2015 customer satisfaction survey). Consistent with the results of the tracking and timing study, this suggests that *Self Reflected* has particular appeal for adult visitors.

Behavioral interactions and movement. Free-choice visitors demonstrated different levels of interaction with the various components of the *Self Reflected* display. Twenty-five groups (63%) read the title label (Figure 2D). Fourteen groups (35%) read the content panel (Figure 2A) only, five groups (13%) watched the video (Figure 2B) only, and ten groups (25%) read the content panel and watched the video. Twelve groups (28%) did not interact with either the content panel or the video. Of groups that watched the video, six groups (40%) watched more than half of the video.

The artists were particularly interested in whether *Self Reflected*, as a two-dimensional display, can stimulate physical movement and spatial interaction. Visitor observations show that the artwork successfully encourages this behavior. After entering the gallery, thirty-nine groups (98%) viewed the piece up close, twenty-five groups (63%) stepped back (though not necessarily at the "sweet spot"), and fifteen groups (38%) moved side to side.

In addition, thirty-three groups (83%) viewed the piece while the lights moved both quickly and slowly, while seven groups (18%) only viewed the lights moving slowly.

Overall interest and first reaction. Free-choice visitors expressed an extremely high level of interest in *Self Reflected.* The median rating of all groups was 5 out of 5, with a mean of 4.75. Two groups were so enthusiastic that they wanted to rate their interest even higher than the maximum of the 5-point scale. Of these, one group cited the accuracy of the illustration and the complexity of its production while the other appreciated the novelty of the artistic approach to communicating science.

Thirty-one groups (78%) stated that they had an *enthusiastic* or *positive* reaction upon first seeing the piece (Fig. 4). No free-choice participants reported a negative response. Sample answers in each category are listed in Table 4.

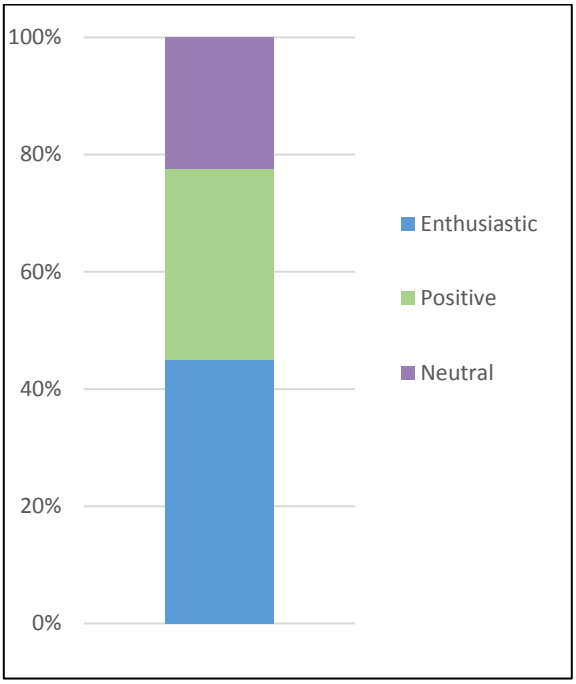

Figure 4. Distribution of free-choice visitors' first reactions to seeing *Self Reflected.*

Enthusiastic	"It's unbelievable, so much work was put into it." "It's beautiful, it's a work of art." "We were in awe." "I love it, it's the nicest thing in the museum right now."
Positive	"It's pretty cool." "Pretty neat." "It's pretty and grabs your attention." "I thought it was cool and I wanted to know how they made it."
Neutral	"It looks like a brain." "It reminded me of an Etch-A-Sketch." "It's huge." "I had no idea what it was."

Table 4. Sample answers given to describe free-choice visitors' first reaction to *Self Reflected.*

Message of the artists. Thirty-four groups (85%) stated that the artists intended to illustrate the function and complexity of the brain through *Self Reflected* (Fig. 5). Six groups (15%) mentioned its artistic or abstract nature, while an additional six groups (10%) explicitly identified the element of the brain perceiving itself. Sample answers in each category are listed in Table 5.

These results show that through self-directed, casual interaction with *Self Reflected,* most visitors clearly understand the artists' intention to communicate the immense complexity of the brain. Combining this result with the tracking and timing data, *Self Reflected* appears to get its message across quickly and effectively, while offering opportunities for engaged visitors to linger, reflect, and take photos.

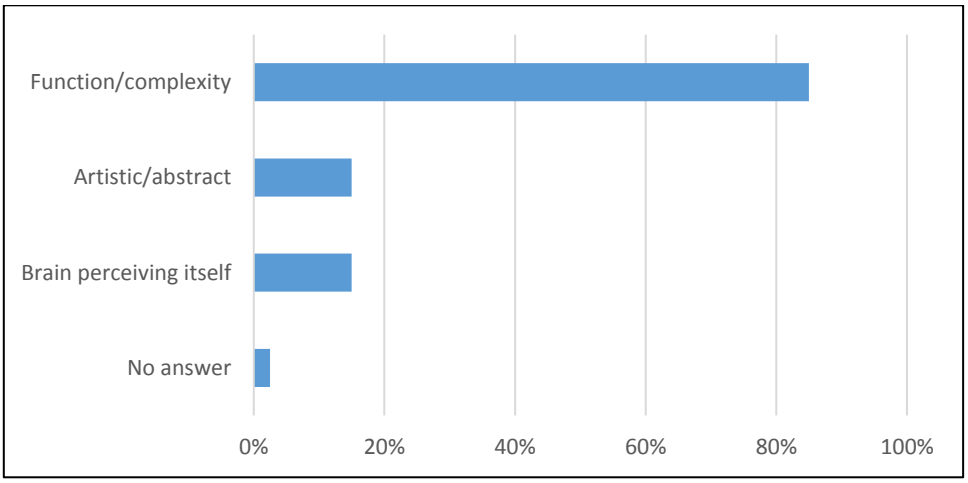

Figure 5. Distribution of free-choice visitors' perceptions of the artists' intended message. The total is greater than 100% as some answers were included in multiple categories.

Function & complexity of the brain	"The movement inside the brain and all of the different pathways." "The brain is a lot more complex than you realize." "The interconnectedness of the brain."
Artistic & abstract nature	"It's the point of coming to a place like this, the point of science communication. It makes you visually struck by something you thought you knew in a new way." "The impact of a single thought." "It's an experience not just information."
The brain perceiving itself	"The brain functions as the brain perceives itself." "Like it says, self-reflected, the brain looking at itself." "Self-realization."
No answer	"I'm not good with that stuff."

Table 5. Sample answers given by free-choice visitors to describe the artists' intended message.

What Was Learned. Fourteen groups (35%) felt that they learned something new about the function and complexity of the brain (Fig. 6). Nine groups (23%) did not learn anything new, often based on their previous level of knowledge. Five groups (13%) did not learn anything new, but mentioned that the art reaffirmed an existing interest in the brain. Two groups (5%) specifically mentioned learning how to interact with the piece. Sample answers in each category are listed in Table 6. Ten groups (25%) did not answer the question—an interesting result given that nearly every group could articulate their thoughts about the artists' message. This suggests that, consistent with the artists' intent, the key takeaway of the experience may be more affective than cognitive.

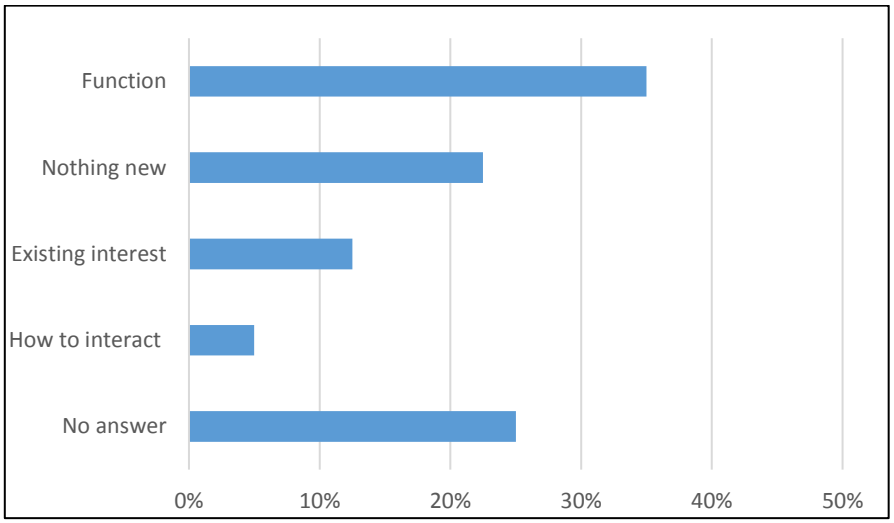

Figure 6. Distribution of free-choice visitors' cognitive outcomes after viewing *Self Reflected*. The total is greater than 100% as some answers were included in multiple categories.

Function of the brain	"How hugely important something is, physically and figuratively, that you cannot see." "How different areas of the brain are connected." "It's much bigger and much more active than I realized."
Did not learn anything new	"Nothing more than I learned in anatomy [class]." "I didn't learn anything new." "I didn't learn so much. It's still confusing and overwhelming."
Reaffirmed an existing interest	"It's a very accurate representation and reminds me of MRI scans." "It reaffirms my interest and appreciation for the brain but may help others who are not yet interested to become interested."
How to interact	"Watching the video tells you to step back to the 'sweet spot.' You need to stand in that spot to really appreciate it."

Table 6. Sample answers given to describe free-choice visitors' cognitive outcomes after viewing *Self Reflected.*

Personal impact. Over half the participants expressed that viewing *Self Reflected* affected their personal view of their brain. Twelve groups (30%) said that they had a greater appreciation for their brain, while nine groups (23%) said that the piece helped them visualize the science of their brain (Fig. 7). Two groups (5%) explicitly said that the experience resulted in no change in how they felt, while 17 groups (43%) gave no answer.

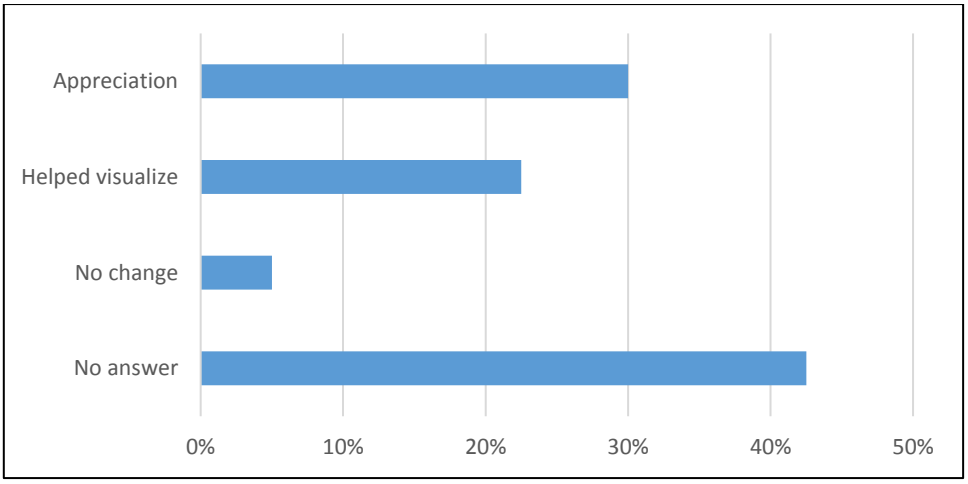

Figure 7. Distribution of how *Self Reflected* affected free-choice visitors' perception of their own brain.

Appreciation	"It made my brain feel powerful because of all of the complexity." "It's a reminder that there is always more to learn in life." "It changed the way I think about my brain."
Helped visualize	"There are many more connections than I thought." "It helped me visualize the flow of energy and information." "It's interesting to think how it's constantly firing."
No change	"It doesn't change the way I think about my brain."

Table 7. Sample answers given to describe how viewing *Self Reflected* affected free-choice visitors' perception of their own brain.

First reaction is likely to influence depth of engagement. Behavioral observations demonstrate that visitors' first reaction to *Self Reflected* is correlated with their level of engagement. While there was no significant relationship between first reaction and whether visitors read the content panel ($p=0.83$), visitors who had a more enthusiastic first reaction were more likely to have also stepped back ($p<0.05$*) for a more

comprehensive look at the piece (Fig. 8). In addition, there was a trend (though not significant; p=0.07) suggesting that the more enthusiastic their first reaction, the more likely the group was to have watched the video (Fig. 9).

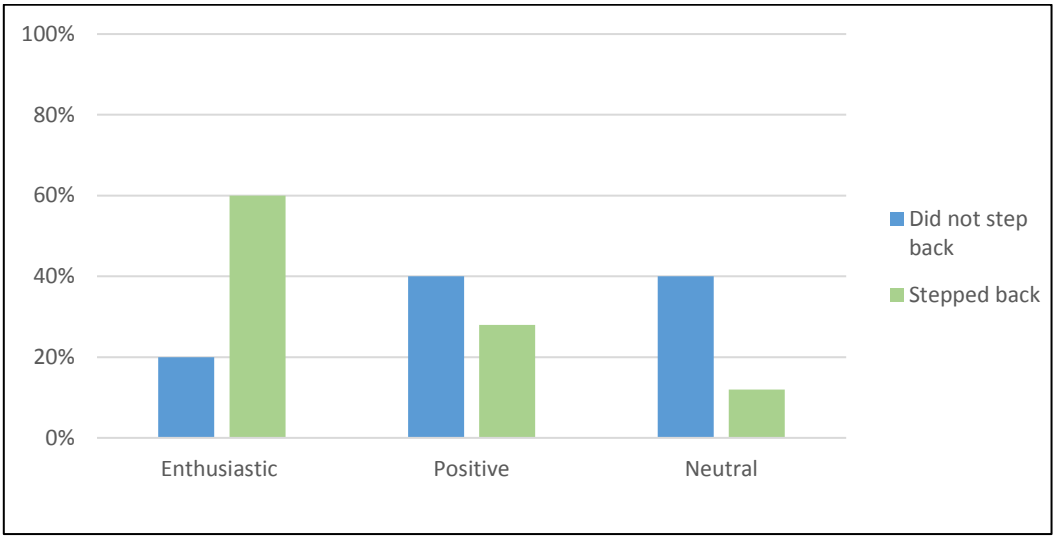

Figure 8. Correlation between first reaction and visitor movement.

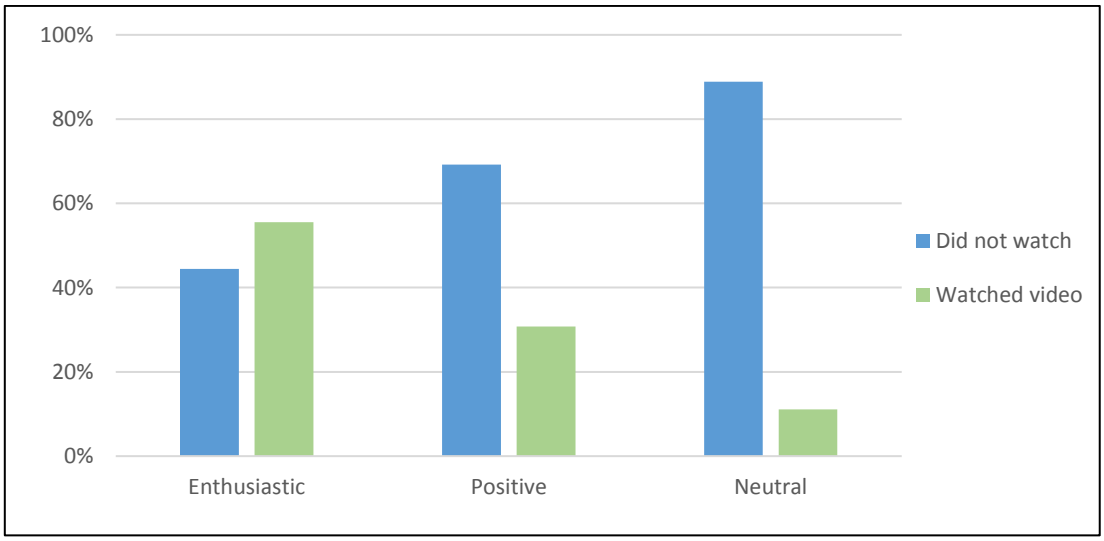

Figure 9. Correlation between first reaction and likelihood of watching the video.

Level of free-choice interaction influences cognitive, but not affective, impact. *Self Reflected* includes multiple components as part of the display, including the piece itself, a short explanatory text panel, and a two-minute video. How does interacting with these different components affect the outcome of the experience?

Results showed no correlation between level of interaction and the perception of the artists' message ($p=0.51$). The majority of participants across all levels of interaction expressed that the primary message of *Self Reflected* was to communicate the function and complexity of the brain. There was also no correlation between level of interaction and change in visitors' perception of their own brain ($p=0.48$).

However, there was a significant correlation ($p<0.01$**) between level of interaction and learning. Visitors who both read the text panel and watched the video in addition to observing the art were most likely to articulate something they had learned (Fig. 10). Of those who watched the video only, one group responded that they did not learn anything new based on their prior knowledge, while the other four groups did not answer. All five of these groups had an enthusiastic or positive first response, and described the message of the piece with respect to the function and complexity of the brain. These results suggest that the text panel is effective in succinctly communicating key facts and concepts conveyed in *Self Reflected*, while the video provides further information for *interested* and *engaged* visitors.

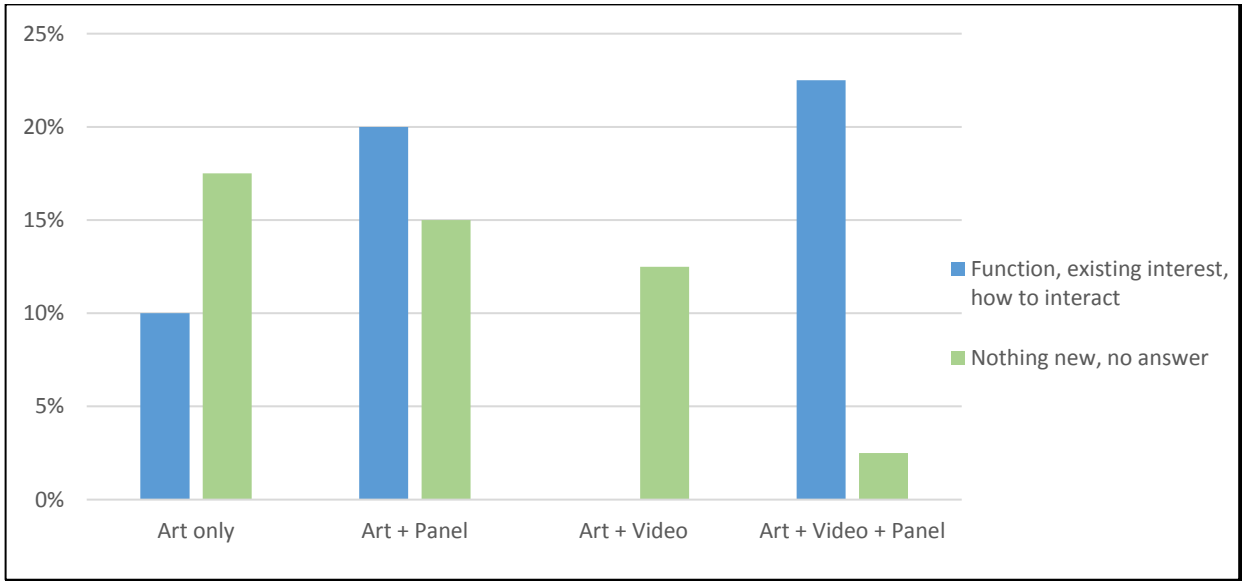

Figure 10. Interaction between depth of engagement and learning.

Groups show deeper learning. Social interaction is a hallmark of informal learning, suggesting that group composition may affect visitors' experience. There was no significant difference in the mean interest rating between individuals and groups (individual mean = 4.87, group mean = 4.76; p=0.3). However, those who viewed the piece with others demonstrated greater learning about the function and complexity of the brain (Fig. 11; $p<0.05$*). This may be due to increased comprehension and retention of information that emerges from conversation with others.

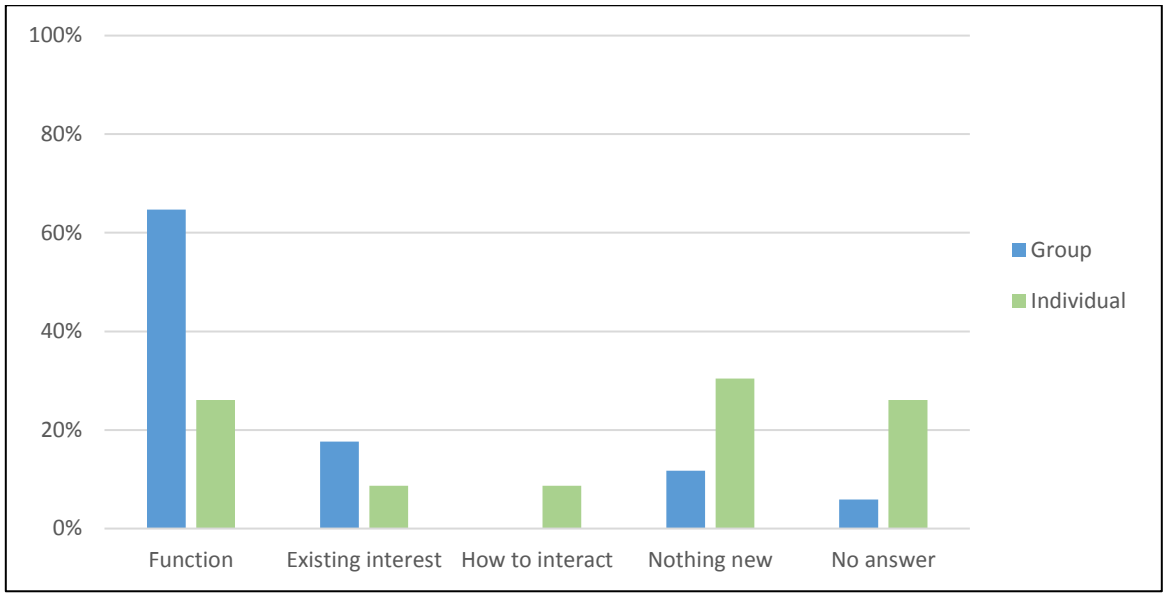

Figure 11. Group composition influences learning about scientific concepts.

RESULTS: OUTCOMES OF RECRUITED ENGAGEMENT

The focus of this phase of evaluation was to understand the reactions and learning outcomes of a random sample of adult visitors, reaching a broader range of perspectives than visitors who freely choose to interact with *Self Reflected* based on their own interest. Demographic characteristics of the visitors recruited for this study are shown in Fig. 12.

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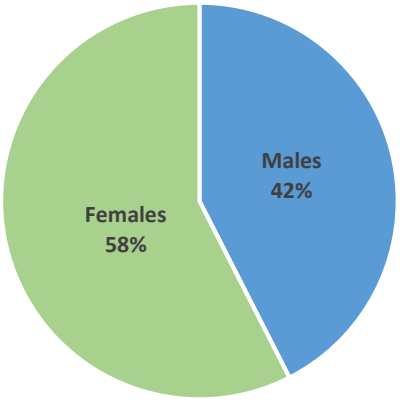

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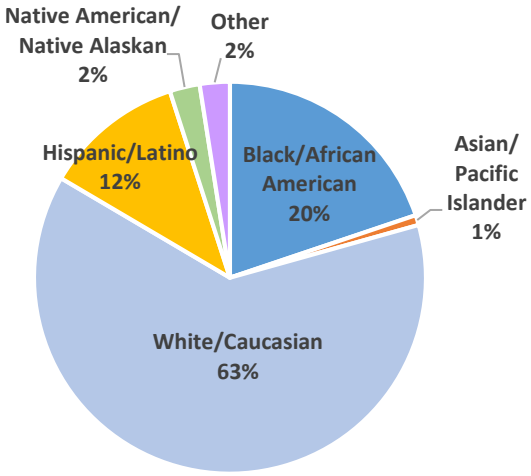


C

Prior Art Experience	Prior Science Knowledge: None	A little	Some	Quite a bit	A great deal
None	1	2			
A little		9	4	1	
Some		2	7	3	1
Quite a bit		1	2	2	
A great deal		1	3		1

D

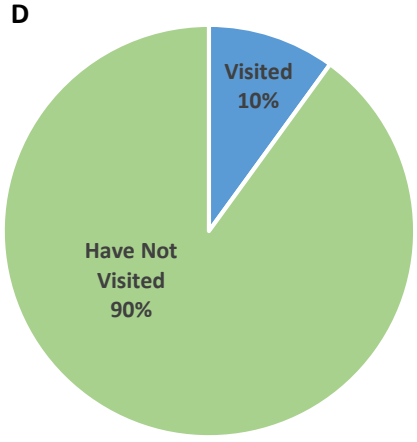


Figure 12. Demographics of visitors recruited for the recruited engagement study. N = 40; one visitor did not complete the entire interaction. A) Percentage of males and females. B) Distribution of ethnic backgrounds. C) Self-characterization of prior science knowledge and art experience. D) Previous visits to the *Your Brain* exhibit.

Behavioral interactions and movement. As expected from prompted participation, recruited visitors engaged more deeply with *Self Reflected* than observed in free-choice interactions. Twenty-nine visitors (69%) read the content panel and watched the video, eight visitors (21%) watched the video only, and one visitor (3%) read the content panel only. Three visitors (8%) did not interact with either the content panel or the video. Of visitors that watched the video, twenty-one visitors (58%) watched the entire video.

Nineteen visitors (49%) actively observed *Self Reflected* from the "sweet spot." During a number of interactions, visitors were observed glancing over at the "sweet spot" as it was described in the video (around 1:28; see script in Appendix A), but then did not physically move after the video was complete. As the subsequent video content may have redirected visitors' attention, it may be more effective to provide the "sweet spot" instructions at the conclusion of the video.

Thirty-six visitors (92%) viewed the piece while the lights moved both quickly and slowly, while three visitors (8%) only viewed the lights moving slowly.

Overall interest and first reaction. The range of first reactions to the work were not significantly different (p=0.95) between the recruited and free-choice samples (Fig. 13). In the recruited sample, one visitor had a negative first reaction because of his general dislike of the aesthetic appearance of gold. There was no significant association between either prior brain knowledge (p=0.15) or prior art experience (p=0.58) and first reaction. The recruited sample also reported a level of interest in *Self Reflected* after their interaction comparable to free-choice visitors. The median rating of recruited visitors was 5 out of 5, with a mean of 4.6.

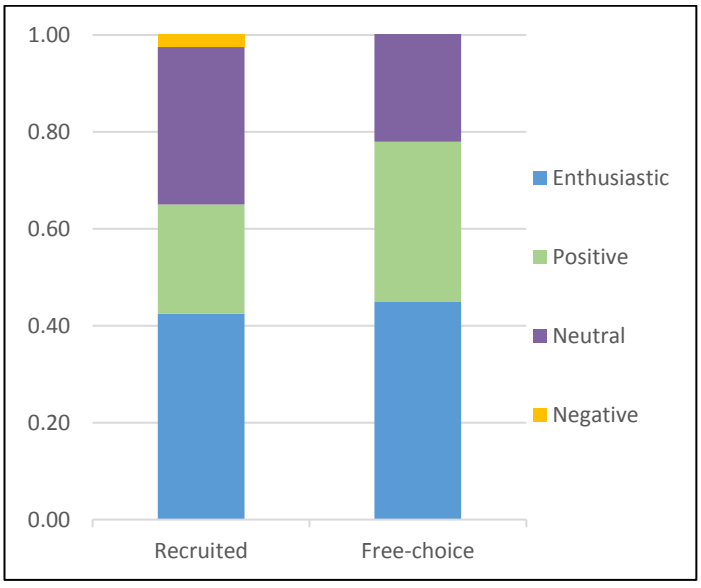


Figure 13. Comparison of first reactions to *Self Reflected* between recruited and free-choice samples of visitors.

Visitors' immediate first reactions were further characterized to understand what aspects of *Self Reflected* made the strongest impression. Twenty-nine visitors (73%) described an abstract reaction to the work, either about its overall aesthetic quality or its personal emotional impact, while twenty-six visitors (65%) cited a more concrete element such as its literal depiction of the brain, a visual analogy to another object, or its lighting, color, or movement (Fig. 14). Sample answers in each category are listed in Table 8.

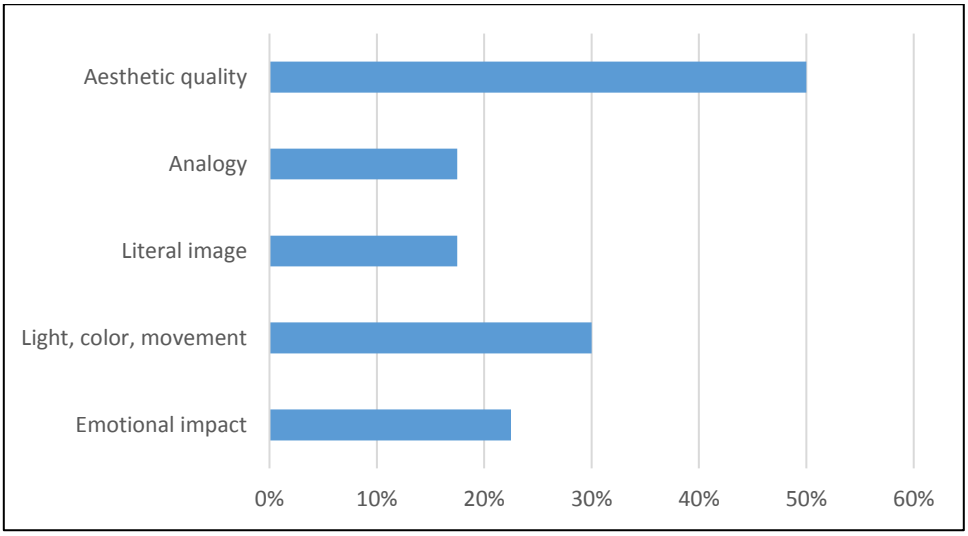


Figure 14. Summary of recruited visitors' immediate first reactions. The total is greater than 100% as some answers were included in multiple categories.

Aesthetic quality	"Impressive. The art is very detailed." "Amazed by this art piece." "It's a beautiful big picture on the wall that belongs in a rich person's house."
Analogy	"I see hair, the way the lines curve. It looks 'under the sea.'" "I thought it was a tree. I'm really focused on the branching pattern."
Literal image	"I can tell it's a brain." "The individual branches are so thin. The collective effect of the individual branches is cool."
Light, color, movement	"It's neat; it feels like it's actually moving with the moving lights." "I love how it goes from multicolored to gold."
Emotional impact	"It's a lot to take in, so much going on in this artwork." "It's mesmerizing."

Table 8. Sample answers given to describe recruited visitors' first reaction to *Self Reflected.*

What Was Learned. In order to investigate the cognitive outcomes of the deeper engagement observed in this study, recruited visitors were asked specifically to identify what they learned about the brain and about the art from their experience. Twenty-six visitors (67%) cited learning something concrete about the

function and complexity of the brain and/or its physical structure, while thirteen visitors (33%) did not learn anything new (Fig. 15). Sample answers in each category are listed in Table 9.

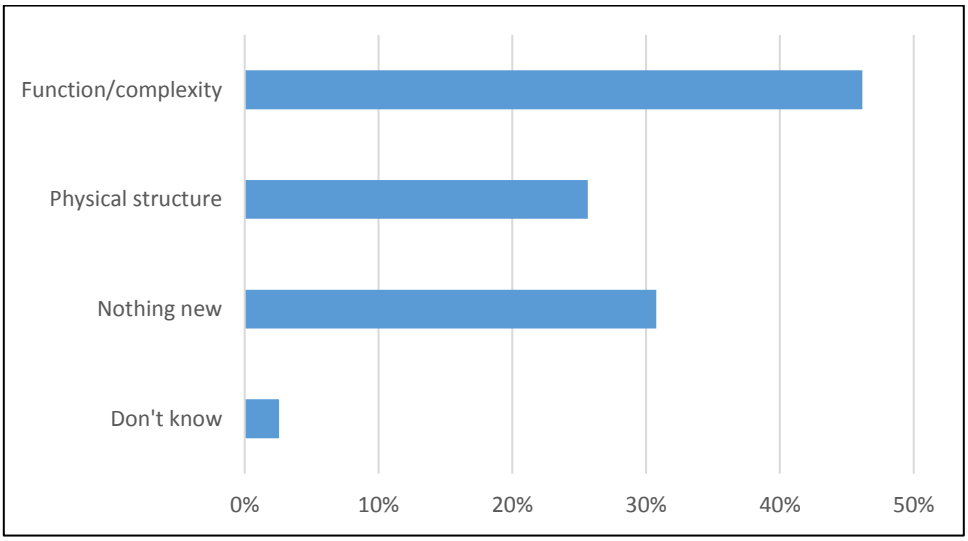


Figure 15. Summary of what recruited visitors learned about the brain from viewing *Self Reflected*. The total is greater than 100% as some answers were included in multiple categories.

Function and complexity	"It all goes through your brain first, then to your body, but it all happens so fast." "I learned just how complex it is. I was like, 'wow, that's really happening?!' And I love that I learned that." "We always thought you only used a small portion of your brain, but this showed us that you use all of it in a visual way."
Physical structure	"There are 500,000 neurons in this slice of the brain!" "[The brain] weighs about 3 pounds."
Nothing new	"Not much new. I'm already familiar with the complexity of the brain." "As a science teacher, I already know a lot, so nothing really."
Don't know	"Not sure."

Table 9. Sample answers given to describe what recruited visitors learned about the brain.

To determine the impact of prior experience, science learning was compared with visitors' prior level of knowledge about the brain. These results confirm that lower levels of prior knowledge are significantly associated ($p<0.05$*) with greater science learning through interaction with *Self Reflected* (Fig. 16). There was no significant effect of prior art experience on science learning ($p=0.43$).

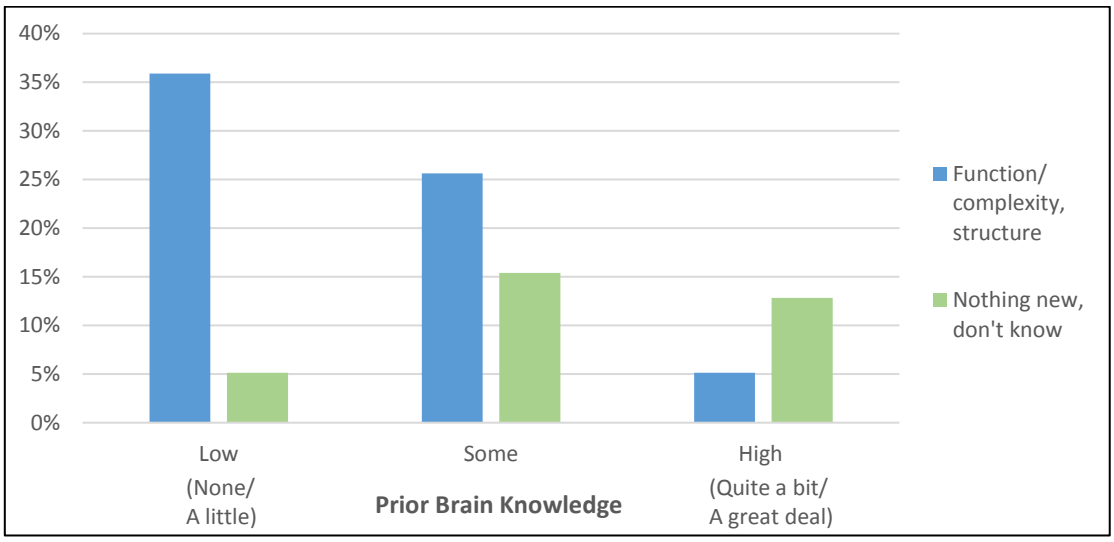


Figure 16. Viewing *Self Reflected* leads to greater science learning for visitors with lower levels of prior knowledge about the brain.

In contrast with the high proportion of visitors who were already familiar with the science content, the artistic techniques used in *Self Reflected* were novel to most visitors. Thirty-three visitors (85%) stated that they had learned something about the artistic process (Fig. 17). Sample answers in each category are listed in Table 10. The most commonly cited learning was about microetching, indicating that this innovative technique is effectively communicated through the supporting components of the display.

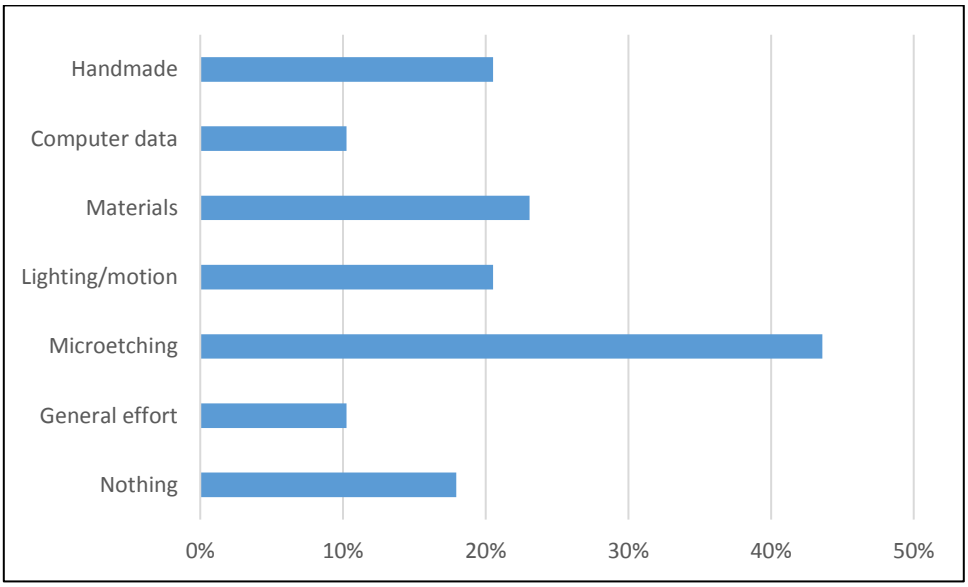


Figure 15. Distribution of what recruited visitors learned about the artwork from viewing *Self Reflected*. The total is greater than 100% as some answers were included in multiple categories.

Handmade	"All done by hand. So crazy that it's only 22 times the size of your brain because it's so big!" "Made by hand, representing some aspect of reality."
Computer data	"It was man made, then matched it with a computer." "Two neuroscientists made this using microetching and gold to create this piece and they used data to plan out exactly how to make it."
Materials	"Black paint first, I think? Then covered in gold." "The techniques, especially the hand blowing process. It looked like metal solder."
Lighting, color, motion	"[I] like the colors, very appealing. Shows flowing movement." "I see they got the light to move across it so you can see the movement of neurons."
Microetching	"It was made with microetching which is a new and progressive way of creating artwork, I suppose." "They used etching into gold and they used scientific data to do that etching."
General effort	"A lot of work went into the piece's creation." "I thought it was interesting that they could recreate a specific section of the brain with such precision."
Nothing	"I didn't learn too much about the art."

Table 9. Sample answers given to describe what recruited visitors learned about the brain. Note that some answers qualified for inclusion in categories other than the one represented here.

Personal impact. Compared to free-choice visitors, the artists' message about the complexity of the brain was perceived by recruited visitors with similar clarity (data not shown). However, the deeper, prompted interaction of recruited visitors inspired greater reflection about its personal emotional impact. Thirty-eight visitors (97%) expressed that viewing *Self Reflected* affected their personal view of their brain, with most saying it made them feel generally positive about or appreciative of their brain (Fig. 16). Nine visitors (23%) said that they felt overwhelmed by the piece, due to its physical scale and/or the immense complexity it represents. Sample answers in each category are listed in Table 10.

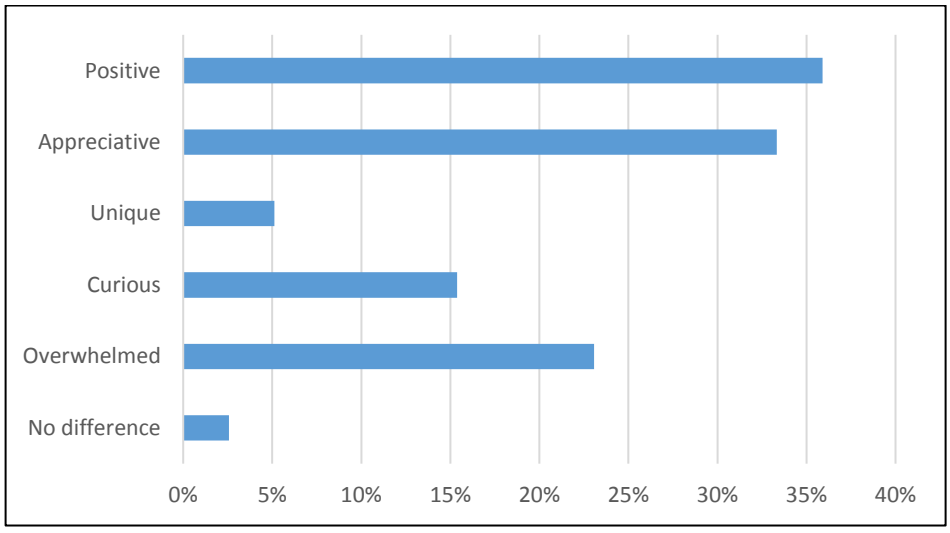


Figure 16. Distribution of recruited visitors' perceptions of their own brain after viewing *Self Reflected*.

Generally positive	"I thought it was cool, and it made me think my brain was cool too." "Awesome, makes me feel good!"
Appreciative	"How delicate and fragile it is. We need to protect it and use it as much as we can." "I didn't realize how much was going on in my brain, and this made me 'get' that."
Unique	"Everyone's brain is really complex and interesting, but my brain is unique and those connections are making me 'me,' and that's really cool." "This illustrated what my brain does in myself."
Curious	"It expands how I think about it. I'm intrigued by it, it makes me want to learn more." "Is there anything that can help me remember things better?"
Overwhelmed	"Anxious, almost…it's almost fragile because there's so much going on." "Active and lonely, but at the same time, important. This piece has a huge presence in the room in terms of composition and scale."
No difference	"It didn't make me feel differently. I already knew [that] my brain, and all brains, are very complex beyond my understanding, so it didn't make me feel a certain way."

Table 9. Sample answers given to describe recruited visitors' perceptions of their own brain after viewing *Self Reflected.* Note that some answers qualified for inclusion in categories other than the one represented here.

Relationship Between Art and Science. As a final question to extrapolate beyond their immediate experience with *Self Reflected*, visitors were asked how art can help people understand science. While five visitors (13%) did not have a specific idea about this relationship and seven others (18%) mentioned the general complementary nature of the two fields, the majority of visitors identified one or more of three specific roles that art can play in the interpretation of science (Fig. 17). Sample answers in each category are listed in Table 11.

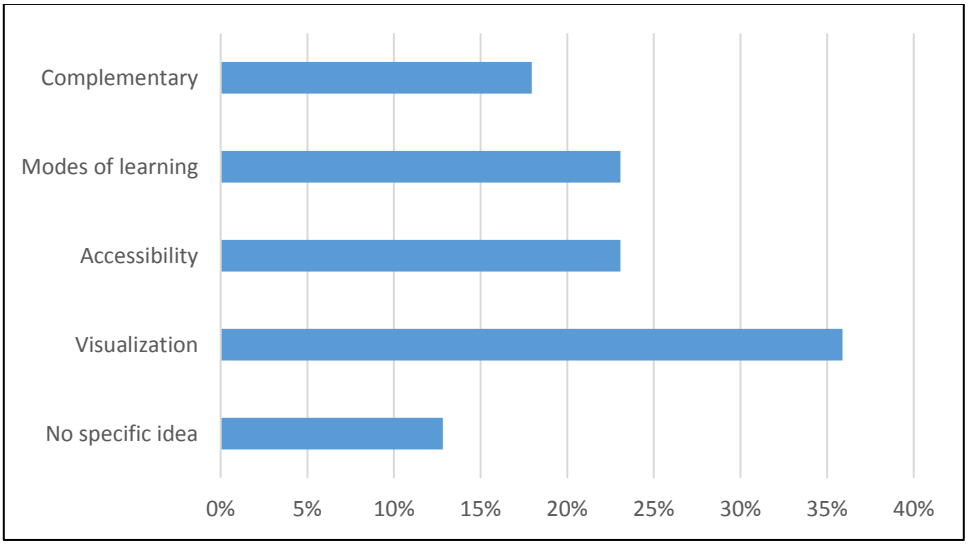


Figure 17. Distribution of recruited visitors' perceptions of the relationship between art and science.

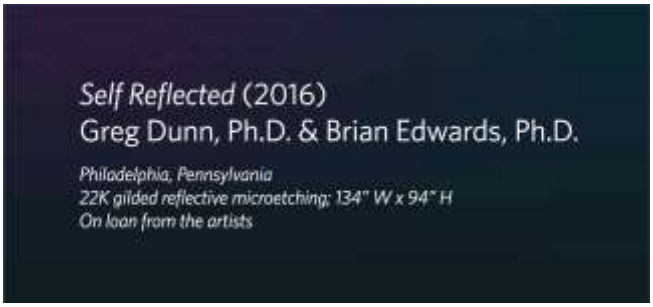
Generally complementary	"Some people in art are dismissive of science and vice versa, but the two combined allow us to understand both far better, and that's amazing." "To me, art is science. I know art & science are supposed to be separate--creative vs. analytical."
Modes of learning	"Some people learn by looking. I like learning hands-on and this piece with the video really works for me, it's not boring." "[Art] helps you visualize [science], especially if you're the kind of person who need to see it or touch it."
Accessibility	"This puts science in a different perspective that's more accessible--less factual, more reflective." "It helps people who aren't interested in science become interested."
Visualization	"Art helps us to see it, put it into perspective. By visualizing [something] you understand it better." "We need some of these complex ideas broken down for us sometimes in a visual way."
No specific idea	"I felt like I understood the brain better after seeing this."

Table 10. Sample answers given to describe recruited visitors' reflections on the relationship between science and art after viewing *Self Reflected.* Note that some answers qualified for inclusion in categories other than the one represented here.

These three roles include: 1) ***broadening modes of learning*** – the visual nature of art presents information in a way that appeals to people who perceive themselves as "visual learners;" 2) ***increasing accessibility*** – the power of art to engage audiences who may not relate to traditional approaches to science; and 3) ***visualizing the unseen*** – the ability of art to illustrate invisible, complex, or abstract scientific concepts.

This evaluation has demonstrated that, as a discrete work of art, *Self Reflected* inspires visitors to grasp the complexity of the brain and see their own brain in a new light. The emergence of these themes around the relationship between art and science suggest that *Self Reflected* may also lead visitors to think more broadly about why merging the two fields is effective and to apply this understanding to future encounters with scientific art.

Label (6.5 in. x 3 in.):



Interpretive Text Panel (24 in. x 24 in.):

Video Script (2 min, 10 sec):

0:00
GREG DUNN: The brain is awesome. There is nothing else in the entire universe which makes you *you* more so than your brain. Every single one of your brains, at this very moment, is exploding with activity.

0:20
NARRATOR: Greg Dunn and Brian Edwards wanted to figure out a way to show the brain in all its beautiful complexity. To show your brain itself.

0:31
GREG DUNN: This is really meant to be one of those pieces that just allows the most jaded neuroscientist to step back from the grind at the lab bench and just take a second and say, "Wow!"

0:47
BRIAN EDWARDS: Four years ago, Greg and I invented reflective microetching in order to realize this vision. Microetchings allow us to visualize brain activity by reflecting light off millions of tiny etches engraved in a golden surface.

1:04
NARRATOR: *Self Reflected* is not an image or a video taken from a brain scan, but it's a handmade and engineered work of art made from scratch.

1:12
BRIAN EDWARDS: We mathematically connected these hand painted neurons into a giant network and then used a computer to figure out how information would travel through this web. The result is like a flock of birds. Each bird is individual but they fly together.

1:28
NARRATOR: When the white light is moving, the best place to stand is in the sweet spot about 12 feet away from the piece in the very center. Notice some of the neural activity responsible for things such as watching how your brain sees the world, reaching out to pet your cat, waltzing across a dance floor. Try to focus on a single neuron as you pass and notice that your brain is constantly changing.

1:59
NARRATOR: *This* is what consciousness looks like. Your self…reflected.

Group Type: Family_____ School_____
A:____ #C____ Age C: M____ F____
M____ F____
M____ F____

APPENDIX B
***Self Reflected* Evaluation Instruments**

***Self Reflected*: Casual Engagement**

Observations

Did the visitor read the label? Yes___ No___

Did the visitor read the content panel? Yes___ No___

Did the visitor watch the video? Yes___ No___

If so, did the visitor watch the majority of the video? Yes__ No__

Did the visitor move to look at it from different positions?
Up close___ Side to side ___ Stepped back___

Did the visitor watch the art while the lights were moving? Slow___ Fast___ Both___ None__

Interview

1. What was your first reaction when you saw the art?

2. What do you think is the message of this art? What did the artists illustrate?

3. What did you learn about the brain by looking at this piece (*if applicable:* and watching the video)?

4. How does this make you feel about your brain?

5. On a scale of 1 to 5 (with 5 being highest), how interesting was this piece to you?

Other comments and observations:

Self Reflected: **Intercept Survey**

1. **Who are you visiting the museum with today?**

___ Family
___ Friends
___ Family and Friends
___ Organized group
___ Other

2. **Including yourself, how many people are in your group *right now*? _____**

3. **Including yourself, how many in your group are MALES? _____**

4. **Including yourself, how many in your group are FEMALES? _____**

5. **Including yourself, how many in your group are:**

____ 0 - 4 years
____ 5 - 9 years
____ 10 - 14 years
____ 15 - 19 years
____ 20 - 29 years
____ 30 - 39 years
____ 40 - 49 years
____ 50 - 59 years
____ 60 or older

6. **Including yourself, how many in your group are:**

____ Black/African American
____ Asian/Pacific Islander
____ White/Caucasian
____ Hispanic/Latino
____ Native American/Native Alaskan
____ Other

7. **Have you been to the *Your Brain* exhibit before?** ____ Yes ____ No

8. **How would you rate your knowledge of the brain? Circle one:**

1	2	3	4	5
None	A little	Some	Quite a bit	A great deal

9. **How would you rate your experience with art? This could include creating art, attending art events or museums, or taking classes about art. Circle one:**

1	2	3	4	5
None	A little	Some	Quite a bit	A great deal

Self Reflected: **Intercept Interview**

Immediately after encountering *Self Reflected*, ask:

1. **What is your first reaction to this piece?**

After completing the experience, ask:

1. **What do you think is the message of this art?** *<probe: What leads you to think that?>*

2. **What is something you learned about the brain?**

3. **What is something you learned about the art?**

4. **How does this work make you feel about your brain?**

5. **How do you think art can help us understand science?**

6. **On a scale of 1 to 5 (with 5 being highest), how interesting was this piece to you?**

Other comments and observations