

The Attestation: Belief Polarization in Visual Action – A Case Study Using Magic (Extended Version)

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This paper describes *The Attestation* (2025), an experimental magic performance and installation which explored how the cognitive mechanisms of causal inference and explanation-seeking can cause different people to reach opposite conclusions about the same visual experience. Despite experts' efforts to avoid misinterpretation, visual media (especially data visualizations) has been met with increasing skepticism by the general public. Magic, which requires building belief in and mitigating scrutiny about the seemingly impossible, is uniquely positioned to act as a case study in investigating belief polarization caused by unbelievable visual experience. In contrast to other academic work involving magic, this piece manipulated the internal structures of magic itself to reveal how a single moment could converge or polarize belief. As trust in visual information erodes, *The Attestation* opens a dialogue about how unexpected inferences can cause people to mistrust images that were explicitly designed to bolster trust.

An extended version of this paper will be available at <https://www.jeanetteandrewsstudio.com/attestationpaper>.

Additional Key Words and Phrases: Contrary updating, scrutiny, belief polarization, causal inference, magic, explanation seeking, data visualization

1 Introduction

The magician shows their hands empty, subtly telegraphing to the audience that everything is what it seems. Then something impossible happens, something that would not have been possible under these “normal” conditions: magic. A ball appears in her empty hand. What if the simple gesture of showing the hand empty, the very thing designed to make the magic seem impossible, instead, for some in the audience, is the gesture that piques suspicion and makes the magic seem less magical? *The Attestation*, the culminating work of the first author's 2025 Visiting Artist residency with MIT, combined an interactive magic performance, installations, short films, and discussions to create a live thought experiment. It explored what may happen if a technique designed to make a visual more believable, instead subverts belief. This presents a novel method to study *belief polarization*: “when two people with opposing prior beliefs both strengthen their beliefs in opposing directions after observing the same data” [14]. The experience was designed to begin an interdisciplinary dialogue about the visual belief formation and causal stickiness — the idea that people will

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attribute the causes of events to the larger context they are presented under, even in the face of contravening evidence. We examine visuals that, by default, are used to heighten belief, and induce in viewers causal associations with those visuals that are designed to heighten scrutiny of them. *The Attestation* utilized magic’s unique visual belief affordances to explore how singular moments could act to converge or polarize visual belief in different sub-populations of people. In particular, *The Attestation*, was designed around convincers, a subtle technique utilized by magicians to build belief. Convincers are an action, object or language that communicates to viewers that the conditions at hand are normal, or, create a condition that makes it far more impossible for something to occur. (For example, a magician pushing up their sleeves before making an object disappear, showing that it will not be possible to secretly hide the object up their sleeve.)

The remainder of the paper is organized as follows. First, we will outline the lines of inquiry that began our collaboration. Next, we review background on the relevant theory of magic, explaining in particular the relationship between causal explanation-seeking and the types of causation that are often applied in magic performances. We show how these causal explanation theories relate to forming belief in the seemingly impossible during a magic performance — and by extension, how that can be subverted. With this theoretical framework in place, we describe *The Attestation*, and conclude with a discussion analyzing what this work exposes about the role of sociological framing in the formation of belief polarization and implications for the fields of visual media and data visualization.

2 Background

Magic has seen a recent surge of popularity as a mode of investigating human perception in the disciplines of neuroscience, psychology, and cognitive science. However, in academic research, magic has primarily been utilized to generate stimuli for empirical research [4, 5, 7, 17]. *The Attestation*, in contrast, applied magic as a functional work of art to serve as a mode of inquiry. This project originated with an investigation into public trust in data visualizations, from a human-computer interaction (HCI) perspective.

Born from a novel, interdisciplinary collaboration between magic, art, anthropology, cognitive science and data visualization, this dialogue can shed light on unexpected systems that prompt viewers to misinterpret visual communication techniques explicitly designed to convey trust and transparency, instead as nefarious and causal. This line of inquiry led the latter authors of this paper, an interdisciplinary team of human-computer interaction (HCI) researchers, cognitive scientists, and anthropologists, to examine magic and magicians’ practical expertise in fostering trust in visual experiences. (An updated, extended version of this paper will give further background on artist-led research, and previous studies on HCI’s relationship to magic [1–3, 9–11, 15, 16, 18, 19, 21].)

2.1 Origins: inspiration from data visualization

We began our joint investigation into the intersection of magic and data visualization with the following observation: Data visualizations work by simplifying complex patterns into easily understood forms. However, for a public inclined to mistrust scientific communication, such simplifications can seem to confirm that the truth is being hidden or faked. (For example, if a graph has a “kink” in the axis scale, that can make the graph easier to read, but can be taken by critics as a sign of manipulation.) Is there a way to design visualizations that takes the potential for suspicion into account, building measures for establishing trust with skeptical users into the form of the interface itself? We sought to intentionally harness magical strategies of communication to develop a conceptual and methodological toolkit for anticipating and defending against adversarial experiences of visualizations. When creating visualizations, garnering trust often proves particularly challenging when presenting information that may seem unbelievable to viewers. Magic

typically presents viewers with unbelievable events. Through in-person iteration, magicians have developed a litany of techniques for bolstering visual trust and mitigating scrutiny. Thus, we were interested in what may be learned from magicians about the notion of a cognitive attack surface. In the context of data visualizations, a cognitive attack surface is defined as a reason for a reader to distrust a visualization. Magicians' discipline-specific, practical knowledge on preventing a viewer's distrust has theoretical and practical applications in visual design.

2.2 The Frame of a Magic Performance in Contemporary Western Society

Magic performances are a case study in refuting skepticism in visual information. Sociologist Erving Goffman presents the notion of a *frame* as a concept for “the culturally determined definitions of reality that allow people to make sense of objects and events” [23] and that they possess a “certain cognitive style” [12]. We define the frame for magic as a performance whereby an attendee expects to be deceived to witness a seemingly impossible event, accomplished via possible, natural means, thereby adopting a heightened sense of scrutiny. Within contemporary Western society, the main colloquial terms that help form the social frame for magic performances are ‘magic show’ and ‘magic trick,’ both of which provide a distinct set of expectations for the viewer. A ‘magic show,’ by nature of its definition as performance, often denotes artificiality or intentionality behind a display and viewers understand that the presenter is not claiming supernatural means. “Magic trick” is the field’s most public and socially ubiquitous term. By being defined as a trick, this term sets the stage by explicitly acknowledging in advance that the content of the performance will be deception. These expectations, in turn, influence where and how they direct their scrutiny, which we will detail in the following section.

2.3 Scrutiny

Due to magic’s frame of foreknowledge of deception, despite not knowing what effects a magic performance will showcase, attendees engage in intense scrutiny towards potential causal mechanisms at play. This in turn, focuses where and how they direct their scrutiny during the impending performance and its environment. As illustrated, the sociological frame of magic performances brackets the experience for the audience as this ‘consensual deception’ (by attending a magic performance, which is grounded in deceptive practices, the audience is willingly consenting to be deceived). Due to this mutual, advance understanding that the magic occurring is a trick, audiences search for naturally plausible, yet concealed and indirect causal explanations. This is how that scrutiny gets applied. Audiences of magic tend towards physical mechanical causal explanations which, combined tells one “what causes what, [and] ... how a certain phenomenon comes about”

When thinking of physical mechanical causes to explain an end effect, consider opening a can with a manual can opener. It is by the mechanical (causal) process of piercing the tin, squeezing the handle and rotating the knob that that can is opened (effect). This mechanical cause explains the effect of the open can.

This mode of causal attribution seeking tends to undergird where viewers’ scrutiny is directed. Magicians typically find that audience’s scrutiny typically falls within one of two categories: tropes and anomalies. Widely held tropes about what types of effects magicians traditionally perform (e.g. levitations, appearances, vanishes, etc.) often preemptively direct a viewer’s scrutiny. Thus, audiences tend to place scrutiny on features that could be a causal explanation for these effects (e.g. possible rigging in the ceiling; places that could conceal an object for later vanishing, such as the magician’s sleeves)

Alternately, viewers may adopt more nebulous attack surfaces in this act of scrutiny. Audiences often scan for any sort of anomalous feature, object or behavior that they can later attribute a causal explanation. This can be attributed to

magic’s sociological frame, which brackets these performances as presenting effects that defy the laws of nature. Thus, this form of scrutiny is often directed at happenstance things that are perceived as abnormal, but are not part of the actual mechanism of the trick (a dropped earring on the floor, a long-leftover remnant of painter’s tape stuck to a wall) and may also include things within the performance itself, such as a gesture by the magician (coughing, scratching an itch, etc.).

2.4 Causal Inference

Why, however, do audiences of magic shows preemptively scan for causes for unknown future effects? Due to the foreknowledge of being consensually deceived, magic shows can act as a bracketed mental space to experience and learn from perceptual and epistemic failure. Because of this foreknowledge, viewers adopt vigilance to possible epistemic threats and adopt this heightened level of scrutiny. Magic performances often acts as a form of “hostile epistemology ... the study of the ways in which environmental features exploit our cognitive vulnerabilities” [20]. If one is successfully deceived, it shows a gap in one’s perceptual or epistemic armor and thus one preemptively guards against it by seeking possible explanations that can be applied to a litany of possible, unknown future effects. This proactive searching for explanations in magic is often paired with retroactively searching for explanations of unexplainable events as a way of “testing hypotheses” [22]. This way, one feels less likely to be deceived in the future. Causal inference Manipulating the causal inferences made by audience members is at the heart of successful magic. Magic may be thought of as artificially creating a structure of fragile causation, “an event [that] would have been some different event altogether under some minuscule variation in spatiotemporal fact” [24]. For this reason, viewers must feel that every aspect of the performance unfolded under the precise conditions implied by the magician, with no ambiguity or other causal possibilities for execution. If a viewer senses that any aspect in the process could have been different, alternate explanations form, and thus the belief in the magic ruptures. Magic aims for very strict belief convergence by way of this fragile causal inference.

2.5 Belief Convergence and Polarization

Viewers must feel that the magical effect could not have occurred under the presented performance conditions in order to seem magical. Consider a ball appearing in a magician’s hand. One must feel certain that the magician’s hand was previously empty, and confident about the impossibility of the event that is to occur. The difference between the magical effect and the initial conditions that led up to it, produce the feeling of magic. Therefore, the conditions of each phase of the magic performance must be conveyed to viewers in extreme clarity.

This process nudges a viewer to feel like they possess probabilistic uncertainty within fixed conditions. To illustrate this type of uncertainty, consider an example from [8]: imagine you roll a six-sided die. Despite not knowing what number will be rolled, you are completely certain about your belief that the number that you roll will be one through six. This sense of the clarity of the conditions gives rise to belief convergence. Magicians are often trying to evoke an experience of probabilistic uncertainty within fixed conditions for viewers. Despite an audience feeling uncertain about the end effect of a magic trick, the conditions at hand seem to have clear likelihoods and thus, when any viewer sees an impossible outcome occur (the magic effect), the outcome feels like it was truly impossible. (Viewers of magic are not making judgments based on actual probabilities, but on deeply held intuitions of the laws of nature (called intuitive physics: “assumptions about the motion [and properties] of objects that are commonly held” [6], such as that objects don’t float, etc.) that they believe with high degrees of confidence.) It is this sense of the clarity aids in belief convergence in magic performances.

Convincer	What it communicates	Typically deployed in
Showing one's hands empty	Nothing hidden in the magician's hands	Appearances and vanishes
Rolling up one's sleeves	Nothing hidden up the magician's sleeves	Appearances, vanishes, transportations and transformations
Pulling or tapping an object to show it's solid (such as pulling on a rope at the beginning and end of the magic effect to prove it's solid)	There are not adhesives or magnets holding the object together, that it is a single rope, that it's not an optical illusion	Cut and restored / Destroyed and made whole
Having an object signed	That the object is not duplicated / that it is the same object	Transportations, transpositions and location discovery effects
Objects pushed out of reach	Object was not directly manipulated by the magician.	Vanishes, transportations, transformations, levitations, sympathetic reactions, mental control / telekinesis, and predictions

Table 1. Common Convincers and Their Uses in Magic

However, when viewers are presented with more ambiguous evidence, it can generate a state Dorst calls *higher-order* uncertainty: uncertainty about the conditions of one's own beliefs. Magic's frame of deception introduces the possibility of higher-order uncertainty. Viewers expect to be deceived, and don't know if they should trust their own beliefs. This is why the internal structure of magic aims for strict belief convergence. If further ambiguity (anything in addition to that of the frame) is introduced, it can lead to belief polarization.

2.6 Cognitive keystones and convincers

To drive viewers to make inferences about the conditions at hand, magicians strive to provide clear visual and cognitive confirmations of events. These keystones are an important structural aspect of magic that builds belief. One form of these keystones is the *convincer*. Convincers are typically a subtle action, object, or language that communicates to viewers that the conditions at hand are normal, or, create a condition that makes it far more impossible for something to occur (Table 1). Convincers often serve a dual function: to negate causal explanations and to heighten a level of how impossible the magic seems. They can communicate about or confirm current, past, and future events, in order for viewers to make certain inferences that account for the non-existent or typically perceptually inadequate or impossible occurrences. Convincers are designed to be almost subliminal and communicate the condition at hand with as little ambiguity as possible. *The Attestation* focused on the manipulation of convincers to introduce ambiguity to create further higher order uncertainty, and thus drive belief polarization.

3 Project: "The Attestation"

The goal of *The Attestation* was for convincers to act as cognitive "attack surfaces" for belief polarization, such that while watching the exact same magic trick, viewers reach opposite interpretations of the moments that are supposed to strengthen their beliefs. The piece sought to explore this goal via the following: if subsets of viewers were exposed to priors whereby the convincer gestures were decontextualized and purely causal, when that subpopulation saw the convincer gesture in the magic performance, our hope was that it would pique scrutiny and nudge them to infer a learned cause for a physical mechanical explanation leading to a breakdown of belief. For those that had not been

exposed to the prior, they would adopt the default function of presenting a point of evidence for belief strengthening and convergence, thus causing groups of viewers to rationally polarize. The piece focused on two convincers — a magician pushing an object away from her on a table, and pushing up her sleeves — and studied how they modulate the cognitive experience of belief. *The Attestation* used performance, installations and films to explore belief polarization and contrary updating in this way. This was an intentionally complex, nebulous work. As an academic installation, it did not need to be simplified, as it was not functioning in magic’s academic stimulus sense, or in magic’s commercial sense, and could therefore embody a hazy, evocative format designed to evoke thought and stimulate conversation.

3.1 An Outline of *The Attestation*

There were four performances of *The Attestation* at our university’s theater and the adjoining green rooms. Members of the university and the public composed the audiences. Upon arriving, attendees were secretly subdivided into two groups. Each group was taken to a different “VIP” waiting area prior to the performance for a pre-performance reception. In each reception, unbeknownst to them, each group was exposed to several instances of causal learning [Griffiths and Tenenbaum](#), which were designed to build up different priors in the separate groups. Waiting areas utilized static and interactive components to expose the group to learn specific causal patterns related to a convincer gesture used during the subsequent magic show. Thus, when the convincer gesture occurred during the performance, those who had not been exposed to the prior would interpret the convincer in its default state, making the magic seem more impossible. However, those who had learned the mechanical cause-and-effect structures of the gesture would be more likely to interpret it as a mechanical cause for the magic, subverting belief.

The priors were designed to be repeated, subtle, and contextually relevant. These stimuli were things that the attendees either had to interact with, thereby performing the motion themselves, are portrayed via film, or are physical still life vignettes in stages that show the cause and effect in various stages of completion. In each space, viewers were presented with a myriad of types of possible (typically invisible or remote) forces that would enact an effect: gravity, magnets and motion activation. The priors strove to be just viable enough for attendees to learn the causal relationship, while also not assigning additional meaning beyond mechanistic causality to each gestural cause in its initial learning phase [Griffiths and Tenenbaum](#). This way, when viewed in live performance, when viewing a similar gesture, that mechanistic causal relationship would be triggered and that cause would become meaningful as a plausible (albeit nebulous) explanation in the given frame of the magic performance. While viewing the performance, the viewers were not to have a concrete idea of the effect that the gesture caused, however, they have learned that this specific gesture always activates something else to happen. When seeing the magic perform the gesture, they would simply have a nebulous sense that ‘something’ that caused and thus explains secret mechanics of the magic trick happened. This sense alone, of a possible opening/inference of a type of a solution is often what affords for the inferential belief chain in magic to take the forked path of non-belief. The solutions that people were made to infer in *The Attestation* were not genuine solutions to the magic effect at hand, to maintain the trade secrets of the magic shown. The work strove to achieve a delicate balance of the audience learning the cause in its corresponding effect, while also not seeming like the audience was directly being prompted to learn or focus their attention in a certain way.

3.1.1 Priors Group 1 (Convincer 1 // Inferred Causation 1): “Learn to be skeptical of objects pushed towards the center of a round surface”. One of the convincers employed in the performance was that objects pushed away from the magician to the center of a round surface are harder to manipulate due to farther spatial proximity, thus making the magic occurring with those objects seem more impossible. This prior however, was designed to demonstrate a causal link that



Fig. 1. Priors Group 1 attendees scanning tickets to enter their “VIP reception.” Attendees would swipe their round tickets to the center of the cylindrical ticket scanning pedestal. When their ticket reached the center, it would activate the pedestal’s internal light, granting them entry to the reception and subsequent performance. This action was intended to form the prior that objects moving towards the center of a circular surface cause mechanical effects.

pushing an object to the center of a round surface always invisibly activates something else. This priming was intended to pique suspicion about moments when objects are pushed out of the magician’s reach on round tables during the performance. Objects that were moved to the center of round surfaces in the priors were typically circular or cylindrical, to build shape bias and help activate the cause and effect relationship response when viewers saw an apple and water glass pushed to the center of round tables during performance. The causal learning components of this space included: attendees scanning their round tickets on a cylindrical pedestal to activate a “check-in” scanner light (Figure 1) and a kettle that starts boiling when moved to the center of a round induction cooktop, a phone charging station of circular, wireless, MagSafe chargers which activated charging when a phone was aligned with the center of the circular pad, etc.

3.1.2 Priors Group 2 (Convincer 2 || Inferred Causation 2): “Learn to be skeptical of fabric being pushed up”. This space was designed for attendees in this group to learn that pushing fabric up is causal, invisibly activating something else. It was designed to pique suspicion about magician pushing up her sleeves, a gesture that in its default function instead signals that there are no places for concealment or hidden causal mechanisms. The causal learning components included a film that depicted lights turning on only when fabric shades were raised.

3.2 Act 1 - Part 1: A short magic performance

The performance evoked the aesthetics of a psychological experiment. Clipboards with surveys, observation mirrors, and chalkboards provided the visual landscape. The audience was seated on the stage. The magician arrived with bags of in-shell walnuts, tangerines, and apples. She ate a walnut and tangerine. Then an audience member chose an apple from

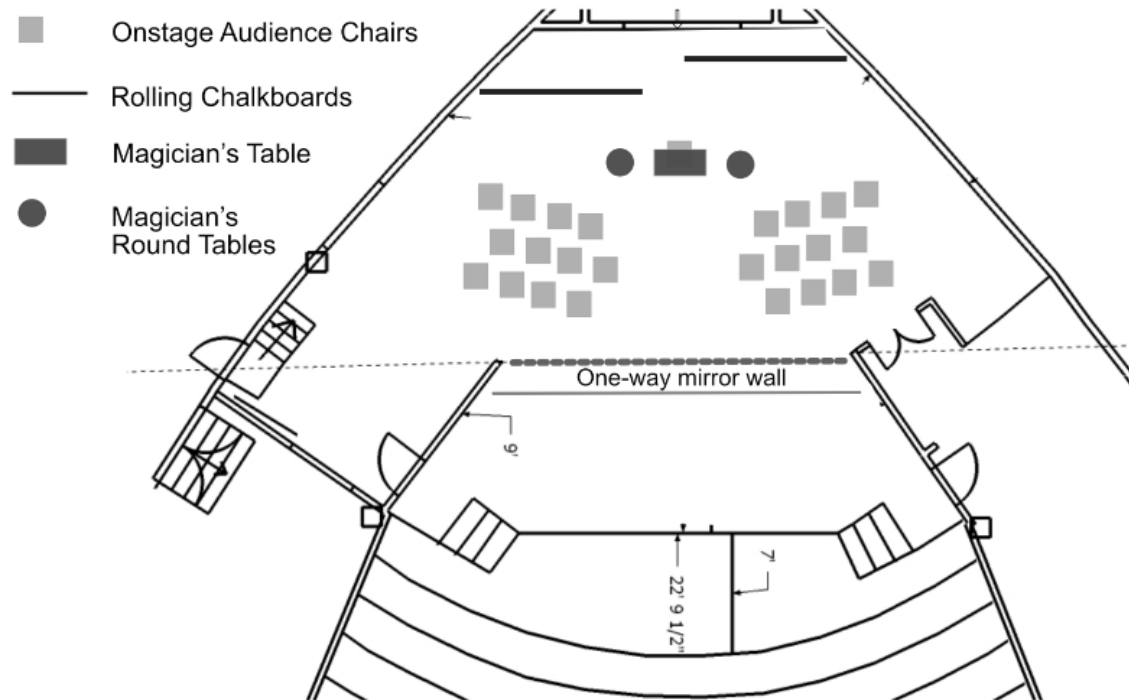


Fig. 2. Stage layout depicting the magician's position with respect to the round tables.

the produce bag. The magician took a seat between two, equidistant, round tables, each of which were barely within her reach (Figure 2). The apple previously chosen by the audience member was placed on the edge of the right-hand round table, barely within the magician's grasp. She then pushed the apple out of reach to the center of the table (Convincer 1 || Inferred Causation 1).

The magician asked to borrow a dollar bill from the audience. An attendee provided one, signed the bill and brought it to the still-seated magician. The bill was wrapped in a thin napkin with the signature visible through the napkin. The magician then took the napkin containing the bill and dropped it into a glass on the near edge of the round table to her left. She then pushed the glass to the center of that table, once again performing the push gesture (Convincer 1 || Inferred Causation 1; Figure 3).

Next, the magician pushed back both sleeves (Convincer 2 || Inferred Causation 2). The magician then leaned out of her seat, to grasp the edge of the napkin that had previously been out of reach, unfurled the napkin, showing that the bill inside had vanished. She then leaned to pick up the apple, cutting it open (Figure 4). Inside was a whole tangerine. Inside of that was the walnut and inside of that was the signed dollar bill, which was returned to the spectator for signature verification.



Fig. 3. Group 1's prior (left) that objects moving towards the center of a circular surface cause mechanical effects compared with (right) the execution of its corresponding convincer (that pushing an object out of reach (here, the center of a round table) makes the object more difficult to manipulate due to its spatial proximity).

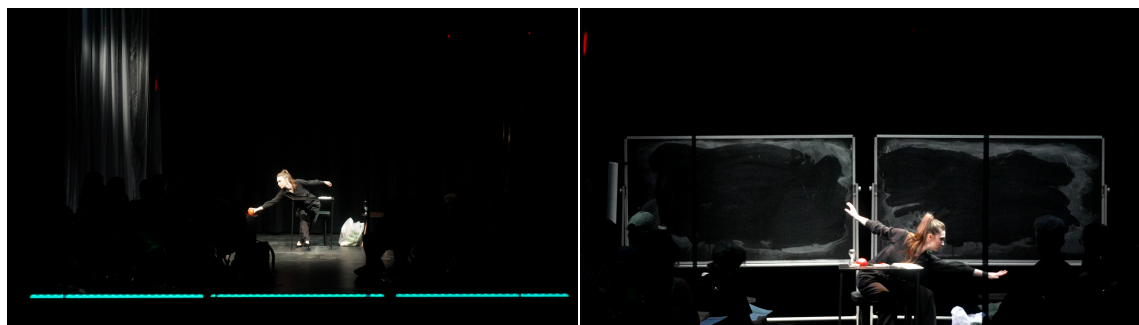


Fig. 4. The magician leaning over to grasp objects that she had previously pushed away from her during the execution of (Convincer 1 || Inferred Causation 1).

3.3 Act 1 - Part 2: Surveying One's Beliefs

Carbon copy questionnaires were distributed to the audience for them to interrogate their beliefs about the performance (Figure 5). Still unaware that they had been divided into subgroups with different priors, attendees repeatedly exchanged the carbon copies with those around them to compare answers. Through secret orchestration, they only exchanged forms with those in the opposing priors group, to evoke a questioning of why people around them had such different interpretations. The audience then received narrow beam flashlights. Those who were in Priors Group 1 had flashlights that projected blue light. Those who were in Priors Group 2 had flashlights that projected yellow light. As a straw poll, the magician wrote the first question from the questionnaires on the chalkboard and drew its corresponding scale underneath. Audience members were instructed to shine their flashlights on the position where they marked their answers on their questionnaires. This was repeated for each survey question, allowing attendees to see how the group as a whole responded (Figure 6). The first two questions, where neither group had received priors otherwise, often showcased convergence. In three of the four performances, some of the subsequent questions pertaining to the convincers produced recognizable polarization between the groups in accordance with the predicted outcome; the colors of lights pooled together at opposite ends of the scales. Others responses were more ambiguous and did not show polarization, but did not show convergence either. This is further detailed in the Discussion.

THE ATTESTATION

Please answer these questions with your initial gut reactions.

Mark your response to each question with a bold "X" where your intuition lies along each scale. (Press hard!)

Keep your answers confidential.

DID THESE ACTIONS HELP SELL THE ILLUSION?

1. When the magician showed that her hands were empty, I became:

More **Skeptical** of the Magic

More **Convinced** of the Magic

2. The bill being signed by the audience member made me feel:

More **Skeptical** of the Magic

More **Convinced** of the Magic

WHERE DID YOUR SCRUTINY LAND?

3A: Did you notice when the magician pushed her sleeves up?

No

Yes

3B: When the magician pushed her sleeves up, I became:

More **Skeptical** of the Magic

More **Convinced** of the Magic

4A: Did you notice when the magician moved the apple and glass away from her to the center of the table?

No

Yes

4B: When the magician moved the objects away from her, I became:

More **Skeptical** of the Magic

More **Convinced** of the Magic

When complete, please tear off this top white sheet and retain as your copy.

Fig. 5. Surveys distributed to attendees mid-performance.



Fig. 6. Straw polling using blue and yellow colored flashlights, which were given to each audience member in advance according to their respective prior group. The distribution of colors projected on the scale revealed the distribution of beliefs held by the audience members.

3.4 Act 1: Part 3: A Reveal

The first act concluded with a twist ending. A lighting shift revealed that there were not two groups, but there was also a secret, hidden audience. The hidden audience had been seated in the main theater seats, behind a wall of one-way mirror spanning the entire proscenium of the theater, and had been observing the onstage audience throughout the performance – an exercise in speculative skepticism.

3.5 Act 2

All three groups were brought together (discovering that they had different pre-performance experiences) to engage in mediated dialogue about belief.

4 Discussion

4.1 Creative Convergence for Learning

Artists possess a rich understanding of how their mediums can be instantiated, exploited, or broken. This type of knowledge can then lend to interdisciplinary collaboration and produce new knowledge in niche aspects of human perception [21], [2], [11]. Artists processing this medium-based knowledge joining with researchers in concerted, specific, yet initially unapparent ways (both parties bringing ‘what only x-medium can investigate’ to the table as opposed to a general ‘let’s make something artistic’) can produce new vantage points. We believe that this artist-driven approach to knowledge-making may bring unexpected research disciplines into conversation, as we saw evidenced

in the execution of *The Attestation*. One meaningful outcome of this work was the manner in which the non-obvious interdisciplinary connections that spurred the work produced further connections to research in previously unconnected topics. The creative applications of cognitive science, data visualization theory, and anthropological understanding in this work allowed not only for the exploration of these practices, but also provided new insight into visual inference. Now, these fields (cognitive science, data visualization, anthropology, and philosophy) share new, mutual ground for dialogue on disbelief in images created to bolster trust. This creative collaboration gives new insight into the interconnected cognitive mechanics of sociological framing devices and their impact on the placement of visual scrutiny, type of explanation seeking that leads to causal inferences, and all of the components converge to produce belief bolstering or shattering interpretations of the same image. We will continue to detail the findings and implications of these insights in the remainder of the paper.

4.2 Deconstructing the Frame of Belief Polarization

The execution of this creative work exposed several novel aspects about the cognitive process of belief polarization. *The Attestation* revealed this intricate relationship between a visual experience's social frame, level and placement of scrutiny dictated by said frame, the type of explanation seeking applied, and the belief polarization mechanisms at play in each of these concepts that create a viewer's interpretation of a visual. For this discussion, we will focus on the 'push an object away' convincer, as that is where we saw the strongest results. In the below section, we will detail *The Attestation*'s most important finding, frame-dependent causal stickiness. This work displayed the outsized impact that a social frame can have on belief formation. We saw the manner in which a frame can induce higher order uncertainty, which can have top-down effects on belief formation. In our instance, magic's distinct social frame of giving viewers advance knowledge that they will be deceived introduces higher order uncertainty. In addition to the frame introducing higher order uncertainty, magic's frame also typically prompts viewers to adopt advance causal explanation seeking. This higher order uncertainty made them more unsure of their own beliefs which afforded us the opportunity to introduce priors to manipulate those unsure beliefs further. The introduction of a prior, generally, introduced further ambiguity into the viewer's cognitive landscape, which is what helped to afford for a later, more divergent interpretation. Specifically, our prior, pushing an object away on the surface, presented the convincer gesture, but as a purely causal action. Here, we saw the relationship between the frame and the prior. We designed a prior that would align with the mechanical explanation seeking that is embedded in the frame: that a mechanical action (pushing an object away) always causes some form of mechanical effect. The groups learning that the convincer gesture has a causal relationship (introducing ambiguity – an additional interpretation to that of the default interpretation) then allowed for these gestures to take on a gap in meaning to operate as inferred plausible, mechanical causal explanations. When nudged with the causal prior, viewers may tend to interpret the ambiguity along the causal line of thinking. (Here, the causal interpretation of the gesture comports with the mechanical, explanation seeking stance that is embedded in the frame of magic performances (as opposed to a general spatial relationship that is communicated in the convincer's default, communicative mode). We showed how the introduction of a prior that aligns with the type of explanation seeking that is baked into magic's frame allowed for a sort of causal stickiness. As the type of causation (mechanical cause) in the prior was aligned with the cognitive style of the frame (seeking for mechanical casual explanations), viewers were more likely to deploy the prior's causal structure as an explanation when seen in performance. This is why we saw people have higher levels of skepticism about the objects being pushed to the center of the round tables, despite those gestures attempting to communicate an opposite message (that it was further away, harder for the magician to manipulate at that distance and thus made the magic more impossible). *The Attestation* demonstrated how

viewers' interpretations of visual information may be derived from an adherence to the cognitive style of a visual's sociological fame and not easily dislodged. It appears that there may be casual stickiness with the frame and type of causal explanation per that frame, and less so to the content communicated by that cause. Hence why viewers of the performances may have had a more skeptical reading of the convincers (for which they received the prior) and inferred as the explanatory cause. This is in stark contrast to the default communicative mode of the convincer, which would have them infer the message that was more narratively cohesive with the performance and would have bolstered their belief in the seemingly impossible occurrence. The Attestation highlights how these insidious and seemingly unrelated causal structures learned in the priors still produce skepticism in viewers when presented with the opposite inferred meaning. Additionally, we show the importance of both the designer and viewer cognitive stances when interpreting information. In the default mode in which convincers are both developed and interpreted, they are strictly a means of communication. The magician uses these gestures to communicate the base state of conditions to an audience. (Such as pushing an object out of reach to show that it is harder for them to manipulate.) However, if a viewer adopts a different cognitive stance about an action, as in our case, of seeing it as a casual action only, this then creates a crack for divergent interpretations. The Attestation displayed the delicate cognitive process by which belief in a single visual image can be bolstered or shattered. We also believe that these findings have great implications in the world of visual information design.

4.3 Magic, metacognition and real-time fact checking

Magic's frame also prompts viewers to adopt an attitude of productive skepticism, due to the consensual deception at hand. Magic's social frame includes a mutual acknowledgment of a skeptical attitude of the viewer. Once an adoption of a skeptical attitude is elicited, allowing for real-time interrogability can help aid in building trust in the presented information. Magic utilizes the audience's productive skepticism to aid in belief convergence by the magician presenting multi-step processes to convince and cement an audience's understanding of the conditions at each stage of a visual process. (e.g. if something is appearing or disappearing, audiences have an intrinsic understanding that it is probably concealed in a proximate location, and so if one is about to make something disappear, they may push up their sleeves to 'prebunk' that explanation.) This essentially functions as real-time fact checking. (However, in this instance, the 'facts' presented in magic are often misleading, which, of course, is the opposite aim of data visualization in particular, but may be in other fields of computer graphics.)

4.4 Limitations in the Execution of The Performance of *The Attestation*

While the execution of this work brought a wealth of new insight, there were limitations and factors that prevented us from making more concrete claims. Despite efforts to control the conditions, the performance and space presented challenges (such as people blocking video monitors showing films used to create the priors). Even with these mitigating factors, we did see that in three of the four performances, there was recognizable polarization between the groups in accordance with the predicted outcome. Some performances displayed this more strongly than others. The belief polarization was more noticeable for the (Convincer 1 || Inferred Causation 1) - "Learn to be skeptical of objects moving towards the center of a space" than (Convincer 2 || Inferred Causation 2). We expected this as the priors in Group 1 (Inferred Causation 1) were more robust in terms of design, and parallelism to the gesture employed in the actual convincer during the performance. In spite of the the situational challenges that were presented, alongside with our advance knowledge that the design of the prior for Group 2 (Inferred Causation 2) was weaker execution, the contrast between the types of priors may contain other factors for further research. (Convincer 1 || Inferred Causation 1) utilized

a movement-based type of causal learning that was undergirded by shape bias (the priors mainly utilizing round and cylindrical objects moving across circular surfaces) that played out in the performance in terms of spatial understanding (the distance from the magician heightening the level of belief in the seemingly impossible, versus the position of the object in relation to the surface of the circular tabletop). It did not employ any largely held public tropes about gestures performed by magicians. Thus, it may prove fruitful to explore the relationships between strength of credences and social versus physical learning in forming explanations. If this work were to be reformatted for experimentation, these variables would be controlled for. As the work utilized visual iconography and processes from standard experimentation practice, despite it clearly being a piece of performance art, it should have been explicitly conveyed to attendees that this was not a rigorous scientific experiment. However, even in spite of the lack of extreme control of situational and environmental factors due to it being a piece of performance art, the work still did produce some interesting theoretical topics for further discussion and research as we will continue to outline. We heard from numerous attendees that their favorite aspect of the project was the Act II discussion. Having a positively valenced polarized belief and lightly structured conversation, afforded people the opportunity to actively question and challenge, not only other's beliefs, but their own, and how and why they arrived at those beliefs.

4.5 Application of *The Attestation's* Theory to Visual Media Research and Data Visualization

The creation of *The Attestation* converged and applied the insights from cognitive science, anthropology, philosophy, and data visualization to visual belief formation that we believe will impact the field by providing new considerations for designers to employ when designing for convergent interpretation in their visuals. The areas that we think are most ripe for researchers' consideration are the way in which a sociological frame can influence the types of inferences that viewers apply, where their scrutiny is directed and how those factors impact convergent or divergent interpretations. When extreme clarity is needed to form a tightly convergent interpretation of a single visual, the impact of the sociological frame may be relevant to take into consideration. There are numerous frames which may contribute to how a visual is interpreted. When researchers and designers have a broad, high level view of the social frame surrounding a visual, this can provide insight into where and what types of scrutiny a viewer might have. Compare the frames of these two images: an image of local voter exit polling shared on social media, and the smartphone interface showing one's Fitbit metrics of the day. Due to the broadly adopted general distrust of all the involved parties behind the image (government, news media, social media tech giants), the political social media post will warrant certain types and placements of scrutiny and causal attributions. Conversely, when viewing one's Fitbit visualization of activity and health data, one had a direct experience and understanding of the physical causes that rendered the metrics, and by extension, the images. Structurally, the social frame can have deep implications for the level and placement of scrutiny, type of explanation seeking and inferred causation. In the Fitbit interface image, there is an inherent trust in one's own lived perception and a more broadly adopted trust in the accuracy of metrics provided by fitness activity trackers. Therefore, unsatisfactory numbers in an image may be primarily attributed to self-blame, perhaps secondarily a tech glitch, however not usually to the overall concept of wearable trackers, the creators of Fitbit intentionally manipulating the results, etc. On the other hand, the online political image may be met with more scrutiny. The frame of the political/social media news is situated in distrust and higher order uncertainty, therefore producing multifaceted scrutiny. Additionally, a viewer may have higher order uncertainty of how ethical they believe that their neighbors are, and how their ethics are reflected in their voting patterns (contrasted to the direct knowledge that they possess about, for example, how many steps that they took that day). The combined higher order uncertainty, and scrutiny across many actors will then be more likely to open more ambiguity for nefarious casual inference. These forms of inferred causation may (unlike the Fitbit example)

provoke polarizing interpretations of the same image by different viewers and an overall lack of belief in the entire system itself. Both images are designed to convey clear, believable images to their viewers, yet due to the frame, not only have different levels of mistrust placed on them by viewers, but also have different paths for where scrutiny is applied and the causes that one would attribute a negative interpretation. These modes of scrutiny and inference show how causal attribution is unlikely to be dislodged from its social frame and how this impacts visual impression.

As visual media and data visualizations are traditionally viewed as methods of communication, the distinctions between communicative and causal cognitive modes of a viewer as outlined previously highlight unexpected causes that would impact the interpretation of an intended communicative device. These may be especially relevant to consider, especially in the case of interactive or moving images. Unexpected causes for belief polarization are also of great relevance when presenting data or visuals that communicate causation (especially with many viewers often interpreting correlation as caution). The theoretical work as highlighted in *The Attestation* can add to a toolkit for preventing causal mirages [19].

There is an increasing demand to garner visual trust in a split second. Thus, having images that are most succinctly positioned for convergent interpretation can afford for more nuanced analysis and lend itself to stakeholders making more informed decisions, etc. In a rapidly shifting visual world where skepticism is becoming the norm, having a deep understanding of the components of belief formation, and how each of those components works in concert with, and can oppose, the others, is critical.

Furthermore, the default convincer stance – step-by-step cementing of each initial condition and the implications of the condition at hand – can be fruitful to explore and apply in the presentation of visual information. This would allow for reducing higher order uncertainty about the visual and help produce belief convergence.

In an era of eroding visual trust, certain types of epistemic gaps may be more deserving of the attention of visual media designers and those in data visualization. The deep interplay between the sociological framing, explanation seeking, and the stickiness of causal inference can provide a framework for belief convergence and polarization in visual information. This work served as a launching pad for research to discover unexpected ways that causal inference can provoke scrutiny in images explicitly designed to bolster that trust that we feel can have critical implications in future visual media design and data visualization.

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