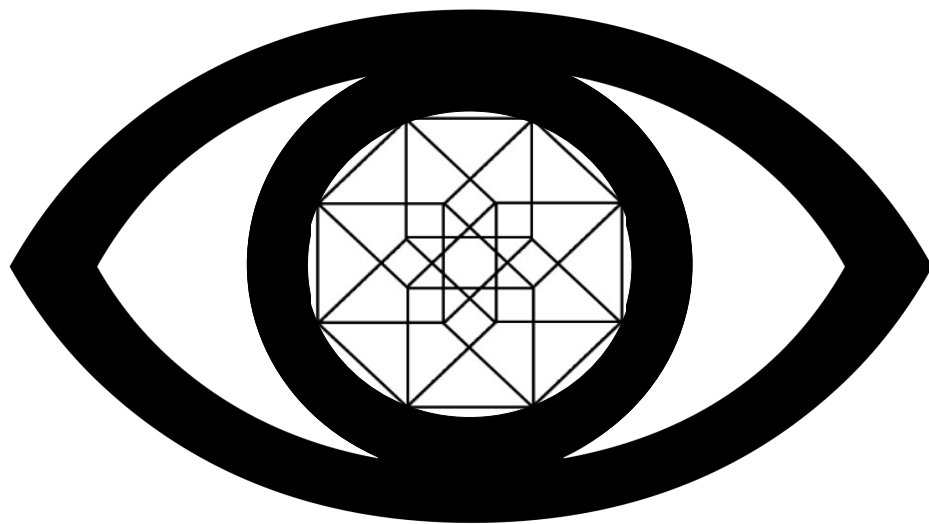


OBSERVATIONS ON INVISIBILITY:
AN INVESTIGATION ON THE ROLE OF
EXPECTATION AND ATTENTIONAL SET
ON VISUAL AWARENESS



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Thesis submitted for the degree of Doctor of Philosophy

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I learned a long time ago that reality was much weirder than anyone's imagination.

Hunter S. Thompson (quoted in Mikulan, 2004)

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Abstract

Observations on Invisibility: An investigation on the role of expectation and attentional set on visual awareness

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This thesis is concerned with the psychology of magic and illusion. In particular it is focused on three illusions, which can be conceptualized as types of invisibility: (1) Illusions of omission—failures to see, (2) Illusions of commission—seeing things that are not really present, and (3) metacognitive illusions—people's false beliefs about their own cognitive and perceptual systems. The work presented in this thesis is set out to explore these illusions through behavioural visual experiments inspired by sleight-of-hand magic tricks. Across three distinct paradigms using stimuli ranging in ranging in complexity from static line drawings, to recorded videos, to live events, I demonstrate that manipulations of observers' expectations and attentional set can result in perceptions of visual events that are variously accurate representations, illusions of omission, or illusions of commission. I also demonstrate that these illusions are often associated with failures of visual metacognition, in that they are generally considered to be surprising and counterintuitive. In addition to these empirical elements of the project, I also consider historical and contemporary connections between experimental psychology and magic tricks. I show that, in some instances, magicians' misdirection techniques anticipated developments by experimental psychology by hundreds of years, and that the idea of investigating the mechanisms of magic tricks and illusions played a key role in the development of experimental psychology as a scientific discipline. Through this combination of historical analyses novel experiments, I show that the integration of magic and experimental psychology has a great potential to drive future research in human cognition and perception.

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Chapter 1

General Introduction



Observations on Invisibility is, perhaps, not a typical graduate thesis in experimental psychology. This work is culmination of four years of investigations into illusions and human perceptual experiences. The empirical work has involved three different behavioral paradigms, 25 distinct experimental conditions, and over 1000 participants have been separately tested. I also ate two wax crayons.

The historical elements of the research included considerations of ancient Egyptian fairy tales recorded on scraps of papyrus, witch trials, ghost hunts, and alleged empirical laboratory evidence of extra-dimensional immortal sprit beings.

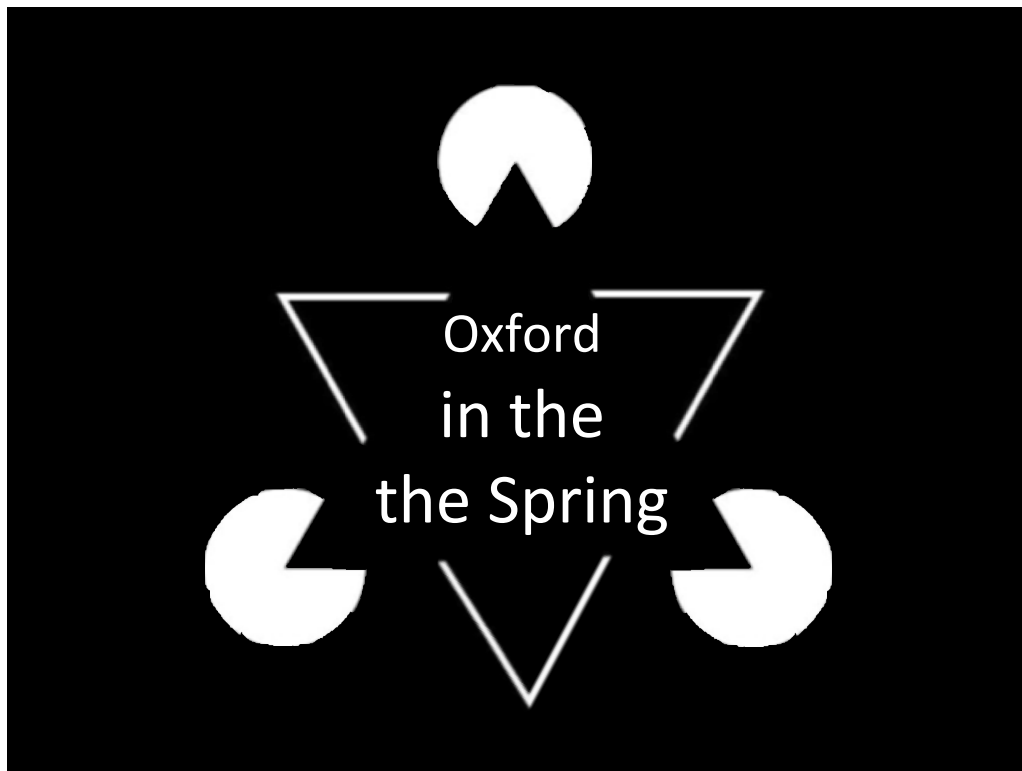


Figure 1.1. An illustration of three types of invisibility. At first, many viewers will see the phrase 'Oxford in the Spring' superimposed on two triangles.

1.1. Three Ways of Looking at ‘Invisibility’

All the elements of this thesis are thematically linked by the concept of invisibility. The Oxford English Dictionary lists three distinct definitions of the word, each of which are relevant here. Invisibility can refer to things that are (1) hidden from sight, (2) unable to be seen, and (3) overlooked or ignored. These definitions correspond with three phenomena that form the central focus of this thesis: attentional blindness, amodal perceptions, and metacognitive illusions.

By way of illustration, consider Figure 1.1. Now, close your eyes and try to reconstruct the image in your mind. Many viewers believe that they have seen a written phrase accompanied by some simple geometric shapes. More specifically, they might say that the figure shows the written phrase: “Oxford in the Spring” with the text being superimposed on two overlapping triangles. However, neither of the observations in the preceding sentence are correct.

1.1.1. ‘Attentional Blindness: Looking and Failing to See

The first type of invisibility considered is relates to things that become hidden in plain sight. Figure 1.2 clearly illustrates that the written phrase presented in Figure 1.1 actually reads ‘Oxford in the the Spring.’ Many people fail to see the repeated ‘the,’ this proofreading error¹ (e.g. Pillsbury, 1887; Sloboda, 1978) is arguably a form of attentional blindness. Attentional blindness refers to failures of visual awareness that are attributable top-down processes. The term which encompasses phenomena such as inattentional blindness and change blindness. In this case, the failure to detect the second ‘the’ cannot necessarily be attributed to a

¹ On the topic of proofreading errors and visual awareness, I would like to invite the reader to consider any subsequent typographical errors that they might discover within this manuscript as interactive demonstrations of this fascinating illusory phenomenon.

failure of low level visual processing- the word is not displayed outside of your visual field, it is not written too faintly, nor is it presented too quickly. Rather, the word seems to be hidden or rendered invisible by top-down processes involving a lack of expectation. This 'look-but-fail-to-see' error is analogous to the concept of inattentional blindness (e.g. Mack & Rock, 1998). The first chapter of this thesis reviews historical perspectives on look-but-fail-to-see style experiments, and also presents a replication of a replication of an early inattentional blindness experiment, first reported by Hugo Münsterberg (1907). My third chapter describes a novel experimental series involving line drawings and written words that explores how observers' task goals can modulate inattentional blindness.

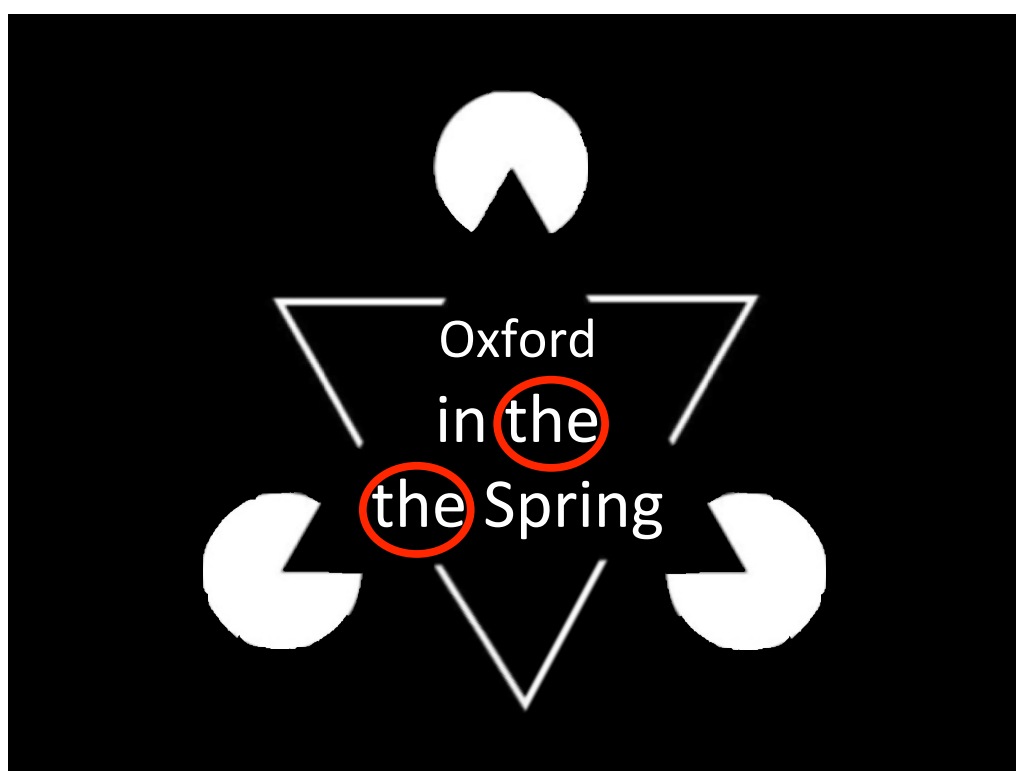


Figure 1.2. An illustration of an illusion of omission— a failure to see. Many people will initially fail to notice that this image contains the word 'the' twice. This is an example of a type of illusion that might be referred to as a 'proof readers error.' It provides an excellent example of how we can look directly at something and yet fail to see it. Physically speaking, the words are not difficult to see. But for many people they are practically invisible (adapted from Eysneck, 2012).

1.1.2. Amodal Perception: ‘Seeing’ Things that are Not There

The second type of invisibility considered relates to things that *cannot* be seen; things that are literally invisible because they do not really exist. Figure 1.3 illustrates that the two triangles that were apparently presented in Figure 1.1 are, in fact, illusory. This part of the image is an example of a Kanizsa figure (e.g. Kanizsa, 1955). Even though the image is actually constructed of three ‘V’ shapes and three ‘pac-men’ shapes, their alignment produces the robust illusory experience of contours or ‘phantom edges.’ Such figures have been shown to activate similar areas of the primary visual cortex as actual visible edges (e.g., Maertens & Pollmann, 2005). For my current purpose, the contours in Figure 1.1. illustrate a second kind of invisibility, which occurs when an image *cannot be seen* because it does not really exist. Such illusions can be categorized as amodal perceptions (e.g. Nanay, 2005); that is to say that they are phenomenological experiences that are not directly drawn from any bottom-up sensory modality. The fifth and sixth chapters of this thesis describe novel empirical investigations of viewers’ potential to ‘see’ phantom objects within dynamic scenes. The Phantom Vanish Paradigm described in chapter five demonstrates that viewers can be induced to falsely report the presence of non-existent objects even in the absence of explicit misinformation, and that this illusion is even more robust when bolstered by written misinformation.

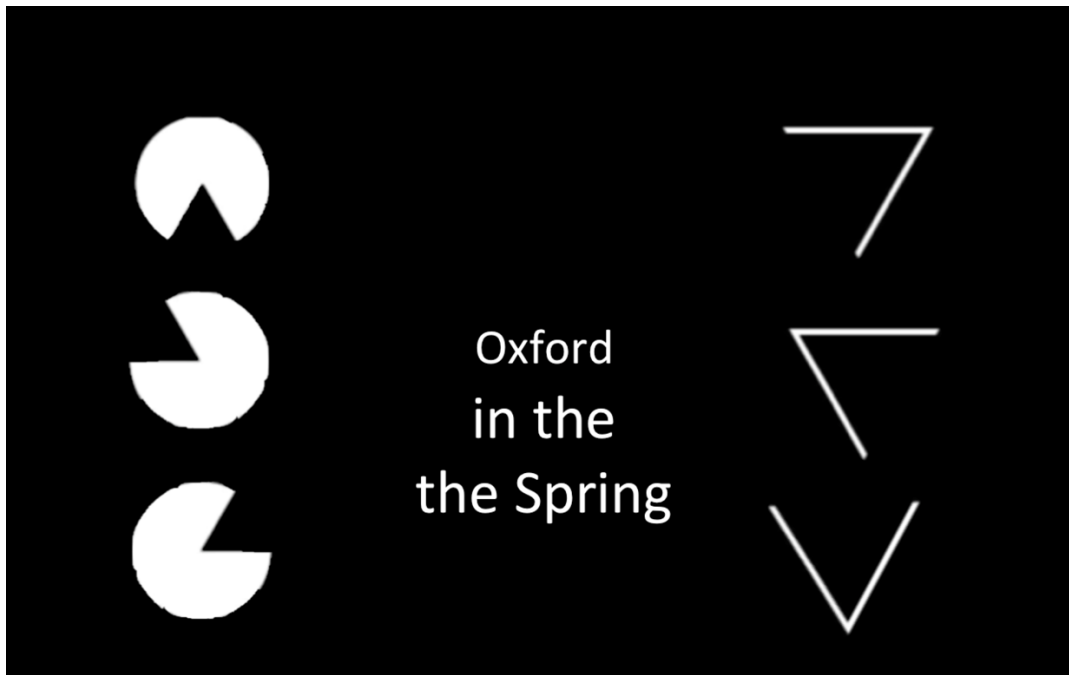


Figure 1.3. An illustration of an illusion of commission— seeing something that is not really there. Despite the fact that the previous figures can be perceived as showing two overlapping triangles, this deconstructed image illustrates that there are actually only a collection of V's and pac men shapes.

1.1.3. Metacognitive Illusions: Erroneously Overlooking or Ignoring

Metacognition is the process of thinking about thinking; it refers to our beliefs and knowledge about our own cognitive processes. By extension metacognitive illusions are false beliefs people hold about their own cognitive processes, for example, people tend to overestimate the accuracy of their own perceptual experiences (e.g. Noe, 2002). The third type of invisibility considered relates to things that are unseen because they are overlooked or ignored. This type of illusion is exemplified in Figure 1.1 by the fact that the first two illusory experiences just described often strike viewers as surprising and highly counter intuitive. People are often shocked that they could have failed to detect the second ‘the’ or that the edges they vividly perceive in the triangles are not really printed on the page. These feelings of incredulity can be conceptualized as resulting from people being confronted with their own metacognitive illusions. That is to say, they demonstrate how people’s self-evaluations of their own visual experiences diverge starkly from their actual visual experience. This concept is very similar to what magicians refer to as the ‘illusion of impossibility’ (e.g. Ortiz, 2014).

In the first two chapters of this thesis, I will present detailed historical analyses of inattentional blindness and the psychology of magic. These chapters describe research and events that have been largely overlooked by contemporary psychologists. Current discussions of inattentional blindness rarely include research pre-dating Mack and Rock’s (1998) book, and I believe that I am the first person to explicitly link the concept to Hodgson and Davey’s (1887) Mal-Observation Report. Similarly, the story of Wilhelm Wundt’s (1879) alleged encounter with immortal spirit people was not itself immortalized in any mainstream psychology texts. Yet in

chapter three, I will argue that this incident provides an important context for more recent efforts to empirically investigate magic illusions.

On a more practical level, both of the behavioral paradigms reported in this thesis also involve striking failures of visual metacognition. The inattentional blindness paradigm described in chapter four was consistently surprising for participants who completed the task, as evidenced by the questionnaire reported in chapter five. And the magical experiences and feelings of impossibility reported by participants in my Phantom Vanish Paradigm could only occur because participants initially overestimated the accuracy of their own perceptions.

1.2 Seeing Through Magic

In the past 15 years, psychologists studying human perception and cognition are increasingly turning towards magic tricks to inspire novel avenues to research (e.g. Rensink & Kuhn, 2015; Thomas, Didierjean, Maquestiaux, & Gyga, 2015). Magicians' development of magic illusions is analogous to the scientific method, with tricks being informally tested on and refined through performances over the course of hundreds of years. Many elements of this thesis are directly inspired by concepts derived from performance magic. Chapter two describes research conducted using magic tricks that anticipated the theoretical implications of inattentional blindness by more than a century (Hodgson & Davey, 1887). Chapter three considers historical approaches on magic performances and methods, including the influence of magic tricks on the development of experimental psychology as a scientific discipline (Wundt, 1879). Chapters five and six both describe novel behavioral paradigms that were developed based on sleight-of-hand magic trick techniques.

In some cases, magicians' knowledge of how to produce visual illusions can be considerably more advanced than that of vision scientists. The Princess Card Trick is

an excellent illustration of this argument. Conveniently, the trick can be readily adapted to the printed page. First take a moment to look at Figure 1.4 and select one of the cards. Hold it in your mind. Now, actually close your eyes, and try to visualize the card. Now turn to Figure 1.5 on the next page. You can see that there are now only three cards. Your card is gone. The effect of this trick is that magician is somehow able to divine one of an array of items that the spectator merely thinks of. The actual method of this trick involves the substitution of *all* of the cards, between the first and second displays. Figure 1.4 depicts the Jack of Diamonds, King of Spades, Queen of Hearts, and the Queen of Clubs, while Figure 1.5 depicts the Jack of Hearts, King of Clubs, and Queen of Diamonds. The original trick is first described in print by T. Nelson Downs (1909), who credits the invention of the trick to Henry Hardin. The original version involves showing spectators physical cards, but the fundamental principle of swapping the entire array of cards, while apparently only taking one, is the same.

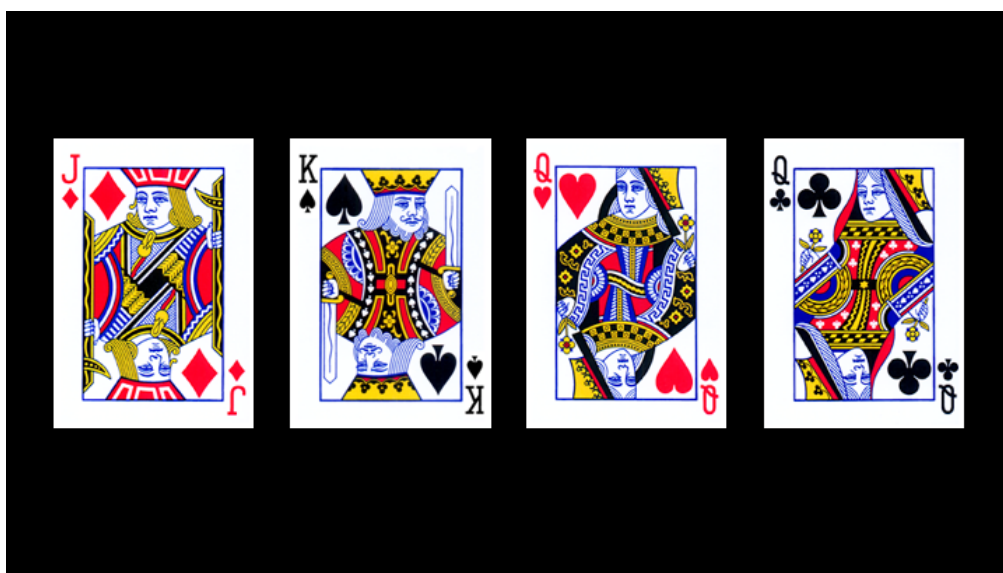


Figure 1.4. The Princess Card Trick-Phase 1. To experience the trick, select one of these cards, then try and focus on the image of that particular card. Then turn to Figure 1.5

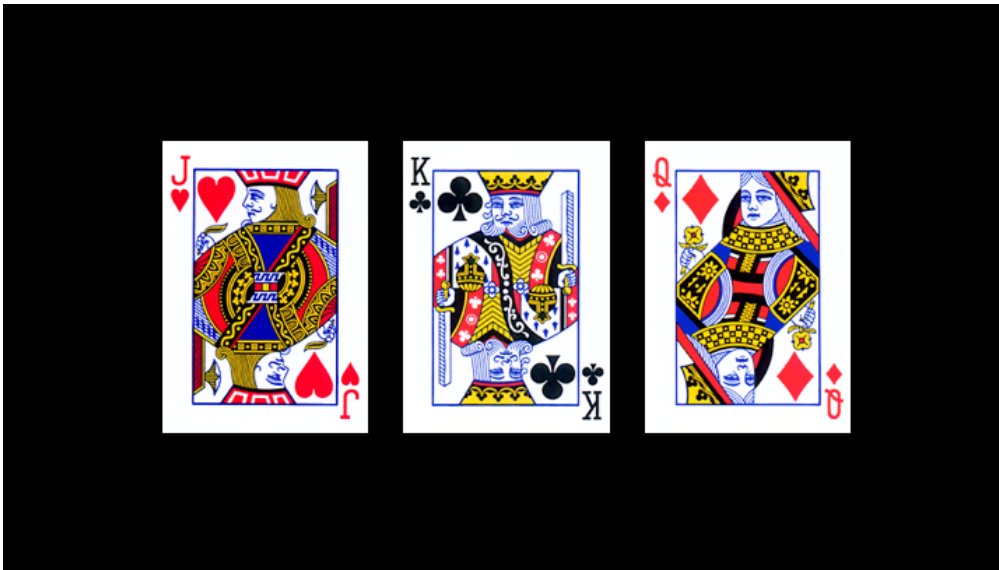


Figure 1.5. The Princess Card Trick- Phase 2. Of the four cards shown in Figure 1.4, only three cards remain, and the card you had been focusing on is apparently gone (see text for explanation).

Considering the illusion from the perspective of experimental psychology, one might describe this as an illustration of ‘change blindness.’ Change blindness refers to a phenomenon wherein viewers will fail to detect changes across scenes, when changes are accompanied by a visual disruption. The term ‘change blindness’ was introduced by Rensink, O’Regan, and Clark (1997) who developed a simple visual task called the flicker paradigm. The flicker paradigm involves showing participants a series of images in a loop. The participant sees one photograph for 240 ms, they then see a blank screen for 80 ms, then a second modified photograph for 240 ms, followed by another 80 ms of a blank screen. This sequence repeats itself until the participant is able to identify the difference between the first and second photograph (see Figure 1.6).

Of note here is the fact that the Princess Card Trick (Downs, 1909) pre-dates formal introduction of the concept of change blindness (Rensink, O’Regan, & Clark, 1997) by 88 years. In other words, magicians developed a method of producing a

robust reproducible illusion based on principles that would not be formally recognized by cognitive psychologists for nearly a century. This is not to suggest that magicians necessarily have a good working understanding of the underlying psychological mechanisms that underpin change blindness, as such an understanding is unnecessary to perform the trick. It does suggest that literature on magic performances represents a rich, relatively, untapped resource for researchers interested in human cognition and perception. In addition to serving as an example of change blindness, one might also argue that the Princess Card Trick exemplifies a failure of visual metacognition. In order for the trick to appear magical or impossible to the spectator, they must implicitly believe that they would notice if all the cards were switched.

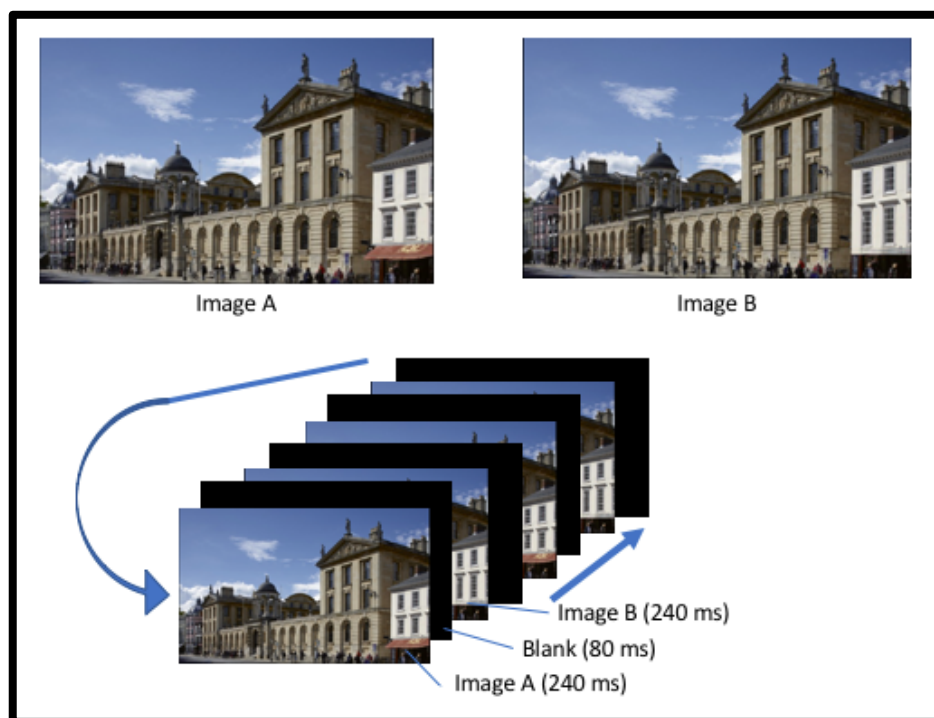


Figure 1.6. Illustration of a flicker paradigm task: Image A contains an awning in the lower right-hand corner, and Image B does not. Participants are shown Image A and Image B, interspersed with a blank screen, in a loop, until they have detected the change

1.3 A Note on the Development this Thesis:

From Initial Project Proposal to Reality

I have been interested in magic since a young age and throughout my time in university studying psychology, I always worked in the domain of human visual perception. I have a distinct childhood memory (although at this point, I know enough to question the veracity of such recollections, see chapter five) of watching a magician perform coin magic at local fair in Upstate New York. I have a vivid recollection of the performer ‘walking’ silver dollars across his knuckles and causing them to fly between his hands, in apparent defiance of gravity. For my birthday that year, I received a copy of J.B. Bobo’s *Modern Coin Magic*, and eventually began giving paid performances at other children’s parties. I kept up the practice of performing professionally during my time at university, when I gained my first research internship with Dr. Jeffrey Mounts’ Visual Cognition Laboratory. In my lectures at university, I was first exposed to classic psychology experiments about the surprising mechanisms of human visual awareness, including the Flicker paradigm (Rensink, O’Regan, & Clark, 1997), the invisible gorilla video (Simons & Chabris, 1999), and the ‘Door Study’ (Simons & Levin, 1999). At this time, I also I began to familiarize myself with the emerging literature of adapting magic tricks to study cognitive psychological phenomena, including experiments based on the Vanishing Ball Illusion and the Vanishing Cigarette (Kuhn & Land, 2006; Kuhn & Tatler, 2005)

When I initially proposed my thesis project, my intention was to create an experiment that would use magic tricks as a tool to investigate the neurological correlates of disbelief experiences. The idea was to design a neuroimaging experiment to isolate the physical part of the brain responsible for the subjective experience of impossibility, i.e. what physically happens when a spectator perceives a

moment of impossibility. Magic tricks, I reasoned could be used as a non-clinical analogue for what philosophers and clinicians have referred to as an ‘aberrant perceptual experience’ (e.g. Maher, 1974, 1999; Davies et al., 2001). At the time, a single experiment (Parris et al., 2007) had been published that involved showing magic tricks to participants while they were in an fMRI machine, and I proposed to create my own set of video stimuli and conduct my own imaging experiment specifically designed to contrast the difference between the subjective of experiences surprise (a violation of expectation) and of disbelief (an apparent violation of the laws of reality), with the idea of shedding light on the neurological mechanism behind the insight that one’s perceptions were deviating from reality.

Upon the commencement of my DPhil studies in 2013, I immediately set about developing a novel set of visual stimuli to use in my proposed imaging experiment. Given that I had no experience conducting research in neuroimaging, I also began taking graduate courses in functional magnetic imaging (fMRI) at the Oxford Center for Functional MRI of the Brain (FMRIB) and magnetoencephalography (MEG) at the Oxford Centre for Human Brain Activity (OHBA). These courses introduced me to the intricacies of designing experiments as well as collecting and analyzing data using modern imaging techniques. For my first year as a DPhil student, I had the privilege of learning first-hand from some leading experts in the field of functional brain imaging. Among many valuable lessons, one of my most important revelations was that the idea of designing my own novel imaging experiment using complex dynamic visual stimuli (let alone securing the funding to conduct such research) was quixotically ambitious. Fortunately, at the same time, I had been taking those neuroimaging classes, I had begun work on behavioral experiment that was designed to examine the role of attentional set in inattentional

blindness, the work was an extension of an ongoing project in my supervisors' laboratory and was significantly more suited to my past experiences studying visual cognition. I also started the process of investigating past research on magic and human perception. That inattentional blindness experiment forms the basis for chapter four of this thesis. I ultimately came to entirely abandon the idea of incorporating neuroimaging methods into my current project, and I adapted the visual stimuli I'd been developing into a purely behavioral experiment that was designed to investigate participants' perceptions of dynamic visual scenes. And the archival research that I had initially intended to form part of a brief general introduction to my empirical work developed into two stand-alone historical chapters.

1.4 The Scope of this Thesis

Broadly, my project has evolved into a consideration of the role of attention and expectation in awareness- how are people's minds 'tuned' from the top-down to allow them to notice (or fail to notice) unanticipated events? On the one hand, specific expectations can result in failures of awareness towards seemingly obvious stimuli. And on the other hand, expectations can generate vivid illusory experiences of non-existent stimuli. Such failures of awareness can be categorized respectively as illusions of omission and illusions of commission. Furthermore, the power and prevalence of these illusions is highly surprising and counterintuitive, because they contradict viewer's metacognitive illusions. These metacognitive illusions can lead observers to disbelieve their own perceptual experiences and, historically speaking, have caused researchers to overlook the significance of new discoveries and developments related to the first two illusions.

This first chapter is an introduction to the overarching themes that connect my empirical studies and my historical research.

Chapter 2, ‘Ghosts of Gorillas Past,’ is one of two historical chapters. It is an exploration of the idea of inattentional blindness, with a particular focus on how the idea of looking-but-failing-to-see had been handled by researchers *before* the concept of inattentional blindness was formally established by Arian Mack and Irving Rock in 1998. The chapter begins with a brief discussion of Mack and Rock’s original paradigm and how it relates to the well-known ‘Invisible Gorilla’ Experiment (Simons & Chabris, 1999). From there, I will consider previous research that had demonstrated the surprising result that people can look directly at, but fail to see, seemingly obvious visual stimuli. Prior to the term ‘inattentional blindness’ being formally introduced to psychological literature, Haines (1991) observed surprising visual errors in pilots who were being tested in flight simulators. Even earlier, Ulric Neisser (1979), conducted a variety of ‘selective looking’ experiments, that served as direct inspirations for the Invisible Gorilla Paradigm. Before they were reconceptualized as examples of inattentional blindness, Neisser’s experiments were largely unappreciated and most of them were never even formally published. I will also present a series of other experiments conducted by researchers interested in anomalous experiences and eyewitness testimony, including AD Cornell’s (1959, 1960) Artificial Apparition paradigm and Hugo Münsterberg’s (1907) eye-witness testimony demonstration. The final historical experiment reviewed is Hodgeon and Davey’s (1887) Mal-Observation Report. I conclude this chapter by reporting an experiment that involved a modern-day adaptation of Münsterberg’s (1907) classroom demonstration about the limits of eye-witness testimony. Münsterberg informally reported a simple paradigm that, in light of contemporary research, can

be conceptualized as having demonstrated central inattentional blindness (Most, 2010) for a 'live' stimulus. Based on Münsterberg's brief description of his experiment, I was able to replicate his procedure for a lecture hall of contemporary participants, and largely replicated the results that he first reported. These findings are discussed in terms of their historical significance as well as their relation to modern developments in inattentional blindness research.

Chapter 3, 'Methods from Madness,' my second historical chapter, examines the history of magic in science and psychology. I begin by presenting evidence that the 'Science of Magic' has undergone a renaissance in the past 15 years. Next, I consider past approaches to describing performance magic, tracing the development of historical records from fantastical descriptions of magic effects to more detailed explanations of performance techniques and methods. Some records exist from ancient cultures that describe fantastical events that might be attributable to performance magic. For example, the Westcar Papyrus describes an Egyptian priest performing miracles in the court of the Pharaoh, around the time the great pyramids were being constructed. While the miracles are described credulously, the effects sound very similar to feats that can be accomplished using magic tricks. This argument is bolstered by later records from other cultures. The ancient Greeks constructed elaborate illusions for their temples, and explicitly described the mechanical methods used to accomplish the acts that they would sometimes attribute to divine miracles (e.g. Woodcroft, 1851). Later writers, like Reginald Scot, would take descriptions of magic a step further by describing seemingly impossible effects, and the methods that could be used to accomplish them naturally, as well as details on how best to perform them. I will also describe how this tension between miraculous and naturalistic interpretations of events would influence early

psychologists as they sought to establish experimental psychology as a scientific discipline.

Chapter 4, 'Now you see it,' is the first of three empirical chapters. It most closely corresponds with the first type of invisibility discussed, which refers to things which are hidden and unable to be seen. In particular, this focuses on an experiment in which written words are effectively hidden in plain sight. The chapter describes a novel experiment designed to investigate the role of attentional set in inattention blindness. The paradigm ostensibly involves a simple computerized picture-naming task, where participants are tasked with identifying line drawings presented in simple four-item arrays. Near the end of the task, participants are unexpectedly presented with a written word, which appears for more than a second, at the point on the screen where they have been instructed to fixate their gaze. The key measure of the experiment is whether or not participants are able to report the presence of the unexpected word. The fact that the pictures in the experiment's primary task did not share any perceptual features with the unexpected word allowed me to specifically manipulate the semantic content of the participants' attentional set by varying their task instructions. My results indicated that while semantic attentional set could modulate rates of inattention blindness, attention that was set semantically was also set narrowly. In other words, participants tended to only notice unexpected stimuli when they were semantically congruent with the task that they were focusing on results that expand our current understanding of the role of top-down factors in noticing and inattention blindness. This chapter concludes with a report of the results of a short questionnaire that was developed to accompany the inattention blindness paradigm presented in chapter four. The questionnaire was intended to assess participants' metacognitive beliefs about their experience completing the

inattentional blindness task. Results indicated that, in general, participants did not believe that they were capable of failing to see the unexpected word stimulus under the conditions of the experiment. These results were ironic considering that many participants expressed this opinion immediately after they *had failed* to detect the unexpected word stimulus. Furthermore, responses also indicated participants prior familiarity with the concept of inattentional blindness did not significantly modulate their rates of noticing the stimulus nor their beliefs about their capacity to notice it. These findings are discussed in terms of their implications for inattentional blindness research methodologies.

Chapter 5, ‘The Phantom Vanish Magic Trick,’ is my second empirical chapter. This chapter most closely corresponds with the second type of invisibility, which refers to things which are unable to be seen, such as the phenomenological products of amodal perceptions. In contrast with the previous chapter, which dealt with failures to see stimuli that were presented in plain sight, this chapter focuses on how participants could be induced to perceive stimuli that were never really presented. This chapter describes a novel behavioral paradigm directly inspired by a sleight-of-hand magic trick. Participants watched a series of magic trick performances, either as pre-recorded videos or live demonstrations. All the performances involved the magician (myself) performing with a single object. After each trick, participants answered questions about what they had just witnessed. The final trick that participants saw was called the ‘Phantom Vanish Trick.’ This trick was not actually performed with any object, but rather the magician pantomimed the actions of holding an object and making it magically disappear. In reality, the trick literally involved making nothing disappear. Nevertheless, some participants reported having seen an object during this last trick. These results represent a new contribution not

only to ‘Science of Magic’ research but, also more generally to our understanding of how top-down cognitive factors influence the way that viewers process dynamic scenes. The results are discussed in terms of ecological versus inferential theories of perception. This chapter concludes with the report of a preliminary second experiment that involved a modification of the Phantom Vanish Paradigm. The experiment was adapted to serve two new purposes, to investigate the role of perceptual priming and to explore the power of explicit misinformation on how participants experienced the Phantom Vanish Illusion. Results indicated that not only were perceptual primes not necessary to create the illusion, but that participants who were exposed to explicit misinformation were significantly more likely to report having experienced the illusion.

The final chapter, chapter 6, contains a general discussion of the work laid out in the preceding historical and empirical chapters. This chapter features a brief recap of the experimental results along with a discussion of their historical context and their implications for contemporary research. In particular, I will discuss the relationship between my findings and the theoretical frameworks of attentional set theory and reality monitoring. The theoretical and methodological limitations of the work will also be considered, with particular attention to the benefits and limits of basing research on participants’ subjective reports of their own visual experiences. I will demonstrate that the theme of people’s visual metacognitive limitations extends to the entirety of this project and discuss the implications of this idea in terms of not only future research, but also science communication. I will conclude by discussing contemporary controversies related to recent developments in the Science of Magic.

Chapter 2

Ghosts of Gorillas Past

A Pre-History of Inattentional Blindness



The following chapter is a review of literature on inattentional blindness. However, the focus of this review is not on the contemporary state of inattentional blindness research. Rather it is on studies that provide empirical demonstrations of inattentional blindness and that also *pre-date* the existence of the term in formal psychological literature. Mack and Rock (1998) are credited with coining the phrase ‘inattentional blindness’ to describe the phenomenon wherein viewers can fail to detect visual objects or events that are fully visible and in plain sight when their attention is otherwise engaged. One of the most striking aspects of inattentional blindness is the fact that the phenomenon is so consistently surprising and counter-intuitive. Mack and Rock themselves expressed explicit surprise and initial puzzlement at how drastically their participants failed to detect stimuli. In this chapter I will argue that researchers themselves have, perhaps ironically, overlooked and failed to appreciate evidence for dramatic inattentional blindness-like failures of human visual awareness that have been recorded by previous researchers.

I will begin by discussing Mack and Rock (1998) and Simons and Chabris’ (1999) iconic Invisible Gorilla Paradigm, I will trace the idea of inattentional blindness backwards in time, considering Neisser’s selective looking experiments (Neisser, 1979), and also Haines’ (1991) experiments testing heads-up-display configurations for airline pilots. From there things get weirder. I will be considering a bizarre experimental series conducted by psychical researcher A.D. Cornell from 1959 to 1960.² Cornell set out to study the concept of hauntings, and ultimately concluded that his experimental methodology failed miserably. But I will argue that he inadvertently designed an elegant inattention paradigm for a live dynamic scene.

² I have previously published the story of Cornell’s experiment as an article for BBC Future (Tompkins, 2016)

Next, I will consider the work of early experimental psychologist Hugo Münsterberg, who, in 1907, reported an informal classroom demonstration designed to reveal the limitations of eye-witness testimony. The last experiment I will discuss is a report written by two psychical researchers, Richard Hodgson and S.J. Davey, and published in 1887. Davey conducted a series of performances using slight-of-hand methods to apparently demonstrate supernatural communication with the spirits of the dead. Before explaining that the effect was a trick, he asked his spectators to provide him with written accounts of the presentation. These written accounts revealed that the spectators would often misperceive and misremember key aspects of the performances, with many of them being unable to explain the slate writing or resorting to the spiritualist explanations. Not only is this one of the first recorded instances of studying spectators' reactions to sleight-of-hand magic tricks, but it is arguably one of the earliest experimental accounts of reconstructive memory and inattentional blindness, or, as Hodgson and Davey phrased it, 'mal-observation.'

2.1 Attention and Misbelief

“Everyone knows what attention is,” begins the oft-quoted passage from William James’ *Principles of Psychology* (1890). “It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought” (p. 404). This particular quote has served as the opening for countless essays and lectures on the topic of human attention. James’ summation was remarkably prescient of modern frameworks about the limits and selectivity of attention. However, the very first phrase, the apparent implication that ‘everyone’ has an accurate metacognitive understanding of their own attentional systems, is arguably false. While everyone might think they know how attention influences the way they perceive the world, what they typically ‘know’ is arguably very different from reality. Many people believe that we only need to look at something, to direct our eyes towards it, in order to see it (e.g. Levin & Angleone, 2008; Simons & Chabris, 2011; 2012). The fact that we will not necessarily see something, even when our eyes are directed towards it, is among the most surprising and interesting results to have emerged from experimental psychological research. Our vivid phenomenological experience of seeing leads us to believe that our visual representations are much more accurate and complete than they actually are (e.g. Levin et al., 2000).

2.2. From Crosses to Gorillas:

Inattentional Blindness Research in the 1990s

For many people today, their first exposure to this surprising failure of visual awareness, and by extension failure of visual metacognition, comes from watching a video of two teams of players, one with white t-shirts and one with black t-shirts, each passing a basketball amongst their respective teammates. Your task, as the

viewer, is to count the number of times players wearing white pass the ball. The 'basketball game' lasts for a total of 24 seconds. A total of 16 passes are made by the team in white. This is not the key measure of the experiment. Crucially, after 10 seconds, a woman wearing a full body gorilla costume strolls through the action, entering from the right side of the video frame. She pauses briefly in the center of the video frame, beats her chest, and then continues strolling off the screen. The woman in the gorilla costume is fully visible for 10 seconds. Nonetheless, when people are focusing on the basketball passes, over half of them fail to notice the gorilla. The video is derived from a psychology experiment published in 1999, by Dan Simons and Christopher Chabris under the title 'Gorillas in Our Midst.' The latest publicly accessible version of the video was uploaded to YouTube in 2010 and has since been viewed more than 17 million times. It is an established part of introductory psychology classes, particularly on the topics of perception and cognition. It has been adapted to public safety advertisements (McVeigh, 2008), and is used as a training demonstration for a wide range of professionals ranging from police officers to sales executives (Chabris & Simons, 2010). The paper itself has been cited more than 22,000 times, and it was also awarded an Ig Nobel Prize in 2004 (Hecht, 2004).

The 'Invisible Gorilla' is perhaps the most iconic example of inattentional blindness. The term was introduced to psychological literature just a year prior to the publication of the Simons and Chabris' gorilla experiment. However, perhaps ironically, the idea that people can look directly at a stimulus and fail to see it had arguably been itself overlooked by experimental psychologists throughout the previous century. In this chapter, I will begin by considering the development of the term 'inattentional blindness' through Mack and Rock's (1998) ground-breaking experimental series and Simons and Chabris' iconic Invisible Gorilla Paradigm. I will

argue that earlier experimental results anticipated these findings, and that many previous researchers had failed to see the significance of these results. Such research includes Ulric Neisser's (e.g. 1979) selective looking experiments, Haines (1991) experiments with airline pilots, AD Cornell's (1969; 1960) psychical investigations, Hugo Münsterberg's (1907) experiments on eye-witness testimony, and Hodgson and Davey's (1887) investigations into slate writing magic tricks.

The term 'inattentional blindness' was popularized³ in 1999 when, Mack and Rock (1998), published an entire book on the topic. The book, titled *Inattentional Blindness*, firmly established the term and the concept in experimental literature. In their book, they describe dozens of experiments, involving approximately 5,000 subjects, that took place over the course of 7 years. They developed the fundamental framework and terminology of contemporary inattentional blindness research. In all of their visual experiments, stimuli were presented to participants as static images on a computer monitor. For example, in one experiment (*Figure 2.1*), participants were presented with the image of a cross, and were instructed to discriminate which section of the cross, the horizontal or vertical arm, is the longer. This portion of the experiment is referred to as the 'primary task.' The cross remained on the screen for 200 milliseconds before it was obscured by a visual mask.

³ The term inattentional blindness actually first appeared in 1992, when researchers noted that several of their participants failed to detect plainly presented visual stimuli when their attention was otherwise engaged: "One striking and unexpected finding is that without attention many subjects had no awareness of the stimulus object, an effect we call inattentional blindness." (Rock, Linnett, Grant, & Mack, 1992, p. 502). However, the 1999 book is usually credited as the first use of the term, and it was certainly responsible for popularizing it.

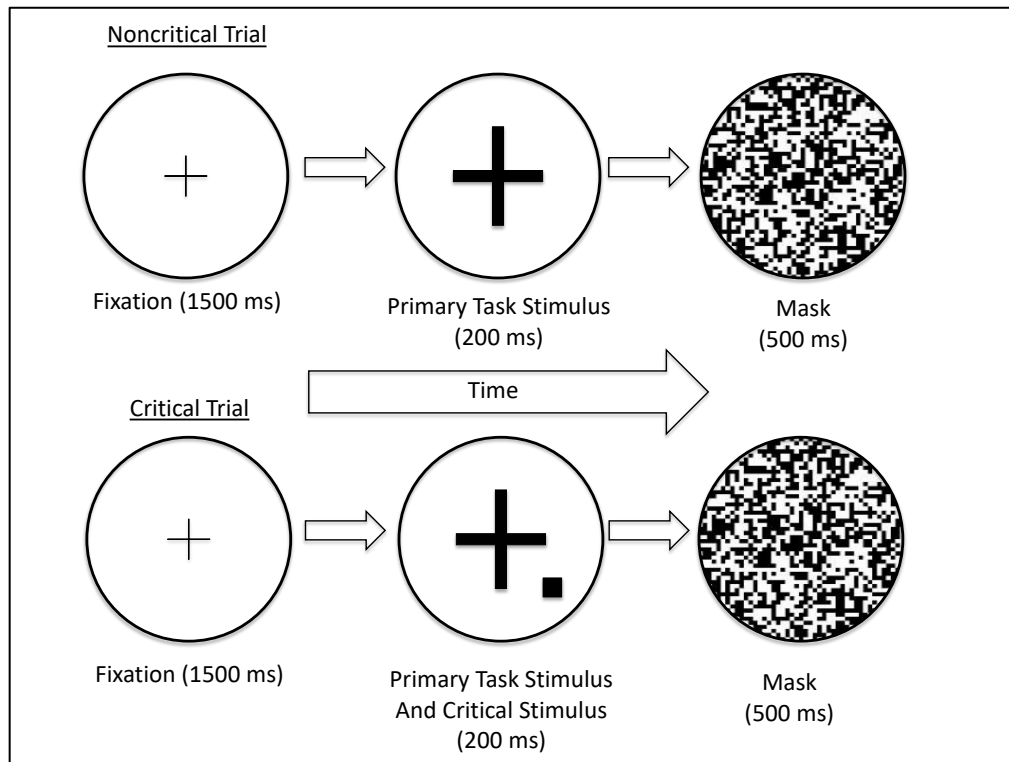


Figure 2.1: Example trials in the style of Mack and Rock's (1998) cross arm discrimination task

This procedure was repeated. Then, on the 3rd trial, the critical 'inattention trial,' an additional stimulus was presented along with the cross⁴. This additional stimulus might take the form of a simple geometric shape, like a square. Participants were not expecting the additional stimulus, and they were not actively searching for it because their attention was engaged in the primary task of discriminating between the arms of the cross. This additional stimulus was referred to as a 'critical stimulus.' Immediately following the inattention trial, participants were questioned as to whether they had seen anything additional on the screen other than the cross. Those who failed to report the additional stimulus were determined to be inattentionally blind to the critical stimulus. After these questions, participants were presented with

⁴ In some of the experiments, the critical inattention trial was preceded by 3 non-critical trials instead of 2.

additional trials that were identical to the critical trial (i.e. the primary task accompanied by the additional critical stimulus). However, each of these additional trials involved different instructions for participants. The trial immediately following the inattention trial was referred to as the divided attention trial. Depending on the experiment, this could be either an implicit or explicit divided attention trial. In the explicit divided attention trial, participants were instructed to look for any additional stimuli, and to continue to engage with the primary task. Alternatively, the divided attention trial might be implicit — participants were not instructed to search for the additional stimulus, but it was assumed that they would be vigilant for it, as a consequence of the questions they had been asked following the inattention trial. The last trial was referred to as a full attention trial; in this trial, participants were instructed to disregard the primary task and were asked if they saw anything additional on the screen other than the cross. The full attention trial was intended to show that perception of the critical stimulus was possible, and that any failures to detect during the critical inattention trial could be attributed to the top-down factor of the absence of attention rather than to bottom-up characteristics of the critical stimulus presentation. This comparison was particularly important for experiments when the critical stimulus was presented very briefly, parafoveally, or when it was accompanied by a visual mask.

The inattention blindness paradigm was initially conceived by Mack and Rock (1998) to address the question of what kinds of features might be perceived pre-attentively. They wrote (p. 5) that they had intended to develop an alternative to the visual search task (e.g., Treisman, 1988), that would allow them to investigate what kind of information viewers could pick-up without attention. Such an investigation would have been impossible to conduct using a visual search paradigm,

given that the search task always requires viewers to actively attend the array. The inattentional blindness paradigm allowed them to eliminate deliberate searching from their experiments. While they initially set out to determine what kinds of visual elements could be perceived under inattention, their results eventually led them to the dramatic conclusion that “*there is no [conscious] perception without attention*” (p. 14, original emphasis). One of the recurring themes throughout the book is how unexpected and counterintuitive the experimental results were for the experimenters. For example, in their cross-arm discrimination task, they initially presented the cross at fixation, with the unexpected critical stimulus appearing parafoveally. In general, about 25% of the participants were inattentionally blind to the stimulus under these conditions. In subsequent experiments, the authors initially reasoned that presenting the primary stimulus parafoveally and the critical stimulus at fixation would modulate the inattentional blindness rates, given that the critical stimulus would be presented directly where participants were fixating. In other words, they assumed that participants would be more likely to notice the unexpected critical stimulus when it appeared exactly where they were looking. To their surprise, the opposite result occurred. Rates of inattentional blindness rose to almost 75% when the critical unexpected stimulus was presented centrally.

Not only did Mack and Rock’s (1998) series of experiments provide overwhelming evidence that people can fail to detect stimuli that are plainly visible when their attention is otherwise engaged, but their methodology also provided a conceptual framework for investigating and describing these failures of visual awareness. Simons and Chabris’ Invisible Gorilla Paradigm (1999) adapted this framework to describe a more natural and dynamic stimulus set. Rather than using simple static geometric shapes that would appear and disappear on a computer

monitor, their experiment involved showing participants a live-action video recording. For their primary task, rather than discriminating which arm of a cross was longer, participants were instructed to count the number of times players passed the basketball. The critical stimulus, rather than being a shape on the monitor, was a person wearing a gorilla costume.

2.3. Ulric Neisser and Selective Looking (1970s)

One of the most interesting aspects of the Invisible Gorilla Paradigm is the fact that it was not initially conceived as a novel experiment, but as a replication of an unpublished experiment that had originally been developed by Ulric Neisser (see Neisser, 1979 for review). Neisser had initially set out to develop a line of research in parallel to selective listening studies. Prior to Neisser's investigations in the visual domain, early cognitive psychologists had largely focused on auditory phenomena to address questions of how stimuli were selectively translated from external sensation to internal representations. Such a focus was arguably due to the relative ease of presenting auditory stimuli compared to visual stimuli in laboratories. Audio-recording and playback technology was available to early researchers long before the refinement of computerized visual displays allowed for reliable and well-controlled presentations of visual stimuli. One such early paradigm was the dichotic listening task (e.g. Cherry, 1953), in which participants wore headphones that played different messages into their left and right ears. Such experiments formed the foundation for some of the first formal cognitive theories and controversies of attention research.

Like the Invisible Gorilla Paradigm, Neisser's paradigm also featured a recorded video of a basketball game for the participants' primary task, however instead of a gorilla costume, his critical unexpected stimulus took the form of either a woman holding a umbrella or a boy with a can of soda. He created four video

recordings of himself and his two co-experimenters passing a basketball back and forth while moving “haphazardly” around a large room. In some video recordings the three players wore light t-shirts, in others they wore dark t-shirts, they also recorded videos where the players wore sunglasses. In each experiment, two videos were electronically superimposed upon one another to create the experimental stimuli. Participants were instructed to follow one team of players, and the teams of players could be distinguished by their shirt color, the presence of sunglasses, both shirts and glasses, or neither. Because of the electronic blending of the videos, the players appeared slightly translucent, and at times players from the two teams might occupy the same visual space, with one player superimposed on other players. In such instances the players would appear to ‘ghost’ through one another.

At first, the videos contained did not involve any elements that conceptualized as an unexpected stimulus. Neisser was only interested in demonstrating that participants were capable of attending to one team while ignoring the other, even when they occupied the same physical space in a dynamic visual display. For example, participants might be shown a video that began with a team of three players wearing white shirts and sunglasses, after a few moments a second team of three, wearing white shirts but not wearing sunglasses would ‘fade in’ to the picture; this second team would sometimes be physically superimposed on the first team. The first team shown was always the ‘target team,’ and the participants had to count the number of passes this team made by hitting a key each time a pass occurred. This paradigm allowed Neisser and his colleagues to vary the perceptual similarity of the two overlapping events by a single feature at a time (the shirts or the sunglasses). Neisser reported that participants were indeed able to complete the tasks with a high degree of accuracy, particularly in the ‘two-cue’ condition, where the teams differed

by *both* shirt color and the presence of sunglasses. This was only slightly worse than their accuracy when they were watching a single game with no overlapping distractor team. Participants' accuracy dropped significantly when there were *no* distinguishing features (players on each team wore the same shirts and no sunglasses). But even in the conditions with no distinguishing features, participants were still able to accurately identify more than half of the target passes, indicating that feature information was not entirely necessary for the establishment of their attentional set.

Neisser considered these results to be generally in line with contemporary filter theories of attention (e.g., Broadbent, 1958) – a visual analog for the results that had previously been demonstrated by dichotic listening tasks. In later experiments however, he attempted to use the paradigm to investigate how unexpected visual events might capture attention, or in his words, “initiate a perceptual cycle.” According to contemporary ecological theories, information obtained pre-attentively was sparse and fragmentary – with no semantic content or even phenomenal impact. Nonetheless, people are, under some circumstances, apparently able to orient themselves to unexpected stimuli. Neisser noted that there was very little work examining exactly how pre-attentive information could lead to an orienting response. In other words, how do we notice novel objects and events if we are not actively searching for them?

At the time Neisser was developing his selective looking experiments, contemporary researchers had promoted ‘early selection’ theories (e.g., Broadbent, 1958; Treisman, 1969), which supposed that conscious perception was generated based on low-level perceptual features of a stimulus. In contrast, late selection frameworks (e.g., Deutsch & Deutsch, 1963), proposed that all information was processed deeply to a semantic level before it entered conscious awareness; thus

stimuli that elicit attentional capture do so because of what they mean rather than their basic perceptual features. One particularly interesting problem that emerged from auditory studies was the ‘cocktail party phenomenon’ (e.g. Moray, 1959) wherein participants would be able to notice their own spoken names even when the names were presented in an unattended auditory channel. While participants were generally unaware of the contents of the unattended messages, their own names would seem to perceptually ‘pop-out’ from the otherwise unattended streams. Such results appeared to represent evidence against early selection theories, in that participants appeared to be capable of processing certain stimuli all the way to a semantic level even when they were not actively attending nor expecting that particular stimulus or message.

Neisser was interested in exploring whether these pop-out style effects could be replicated in a visual domain. To this end, he created a new set of experimental videos to investigate the problem of the pick-up of unexpected visual information. Once again, the videos included two teams of players passing basketballs, but this time they introduced an unexpected event: a young woman carrying an open umbrella strolled through the game, appearing on screen for about four seconds. Neisser briefly described informal pilots that indicated that participants who were attending to the number of passes often failed to detect the umbrella woman, while participants who watched the video but were not told to count basketball passes had not difficulty detecting her. He also referred to the results of one in press (ultimately unpublished) study which resulted only 21% of all naïve observers who were tasked with counting basketball passes detecting the umbrella woman. He commented that this was “a remarkably small proportion when one considers how prolonged, odd, and obvious her appearance on the screen actually is” (Neisser, 1979, p 215). In other

conditions, they apparently obtained similar results when the boy with a soda can was substituted for the umbrella woman, and they were able to increase the rates of noticing by filming an alternative video, where the umbrella woman paused in the center of the game's action and proceeded to perform "a little dance number."

Today, the most complete records of information pick-up in selective looking experiments can be found in Neisser's (1979) book chapter. In this chapter, Neisser references a conference presentation (Neisser & Dube, 1978, as cited in Neisser, 1979) as well as two other papers in preparation (Becklen, Neisser, & Littman, 1979; Neisser, Dube, Karis, & Bahrick, 1979, as cited in Neisser, 1979). Of these, no records of the conference presentation exist today, either in the archives of the Eastern Psychological Association (the original conveners of the conference), or at Cornell University, where Neisser had conducted the research, or at Emory University, where he subsequently took up a subsequent academic position, and neither of the papers cited as being 'in preparation' were ever formally published.

Contemporary visual scientists have argued that Neisser's selective looking experiments initially failed to engage researchers' attention because the failures of visual awareness they demonstrated were so counter-intuitive and unbelievable (Rensink quoted in Carpenter, 2001). Interestingly, there is no mention of Neisser's selective looking experiments in *Inattentional Blindness* (1998). Mack and Rock were unaware of Neisser's experimental paradigm when they initially developed and tested their inattentional blindness paradigm, although they did become aware of the literature as they were writing-up their research for the book (Mack, 2017, personal correspondence). Nonetheless, the conceptual framework developed by Mack and Rock arguably paved the way for Simons and Chabris (who had previously worked with Neisser and were familiar with his work) to re-conceptualize the selective

looking task as an inattentional blindness paradigm. While the short live-action YouTube version of the task is the version that would become famous, they actually began with a more direct replication. They used digital manipulation to render the basketball players semi-transparent, as Neisser had done using film manipulations and silvered mirrors. They planned to simply use a woman with an umbrella as their critical stimulus. By chance, on the day that the video stimuli were being filmed, one research assistant happened to have a gorilla costume with her that she had brought to use for a completely different laboratory experiment, and so they also filmed a version where she wore the costume (Wiseman, 2017, lecture delivered at SOMA conference).

2.4. Inattentional Blindness for Simulated Airplanes

It should be noted that one empirical study of selective looking/inattentional blindness was conducted in the time between Neisser's selective looking experiments and Mack and Rock's computerized paradigm. Haines (1991) reported a series of experiments he conducted while working with NASA to develop computerized heads-up displays (HUDs) for airplane pilots. The participants in his experiments were eight commercial pilots and the study called for them to use an immersive flight simulator that had been modified to include a novel HUD. The HUD included navigational and logistical information and was embedded directly into the windshield of the cockpit, so that the information from the display was superimposed directly over the external visual input. The engineering concept behind the HUD was that the information overlay would be safer and more efficient because it would allow the pilots to maintain their fixation on the cockpit window without having to glance downwards to an instrument panel below. In one of the experiments, the pilots were tasked with completing a simulated landing procedure. In stark contrast to the

hypothesized increase in efficiency and safety, four of the pilots committed critical errors that would have resulted in catastrophic crashes had they occurred outside of the simulator. Two of the pilots completely failed to detect an unexpected obstacle (another plane sitting on the runway where they were supposed to land) and the other two detected it too late to avoid an accident. Interestingly, the pilots and even the experimenters were incredulous of these outcomes. They initially attributed the problem to equipment error, before they replayed the recorded simulations. One of the participants noted that if he had not been shown the tape of his simulated run, then he would not have believed that it was possible for him to have failed to detect such an obvious obstacle. While Haines's write-up pre-dates the term 'inattention blindness' and makes no reference to Neisser or selective looking experiments, this procedure is strongly analogous to the inattention paradigm- the pilot's primary task was to land the plane they were flying, while the critical unexpected stimulus was the unexpected obstacle on the runway. Furthermore, the pilots' surprise at their failures is an effective illustration of a failure of metacognition, as it relates to inattention blindness.

2.5. Inattention Blindness for an 'Experimental Apparition' (1959-1960)

Following on from the popularization of the invisible gorilla experiment, attention research has exploded with 'sights unseen,' including simple geometric shapes, motorcycles, simulated assaults, pirates, unicycling clowns, and, of course, gorillas- intruding on basketball games and even lurking in radiological scans (Mack & Rock, 1998; Kennedy & Bliss, 2013; Chabris, Weinberger, Fontaine, & Simons, 2011;

Näsholm, Rohlfsing & Sauer; 2013; Hyman, Boss, Wise, McKenzie, & Caggiano, 2010; Castel, Vendetti, & Holyoak, 2012; Simons & Chabris, 1999; Drew, Vö, & Wolfe, 2013). But, if you know where to look, evidence for inattention blindness can actually be seen in experimental literature that pre-dates even Neisser's selective looking experiments. It is easy to understand why these experiments may have been overlooked by psychological researchers, given that none of them were formally published in psychology journals. Working backwards from Neisser's selective looking experiments, the most recent experimental demonstration of inattention blindness was a study reported by a parapsychologist, AD Cornell (1959, 1960), of experiments he conducted around Cambridge. While Cornell had clearly not intended to study human visual attention, his reports contain enough details to reveal that his experimental paradigm was surprisingly prescient of later inattention blindness research. We know that on the 28th of May 1960, at precisely 7:40pm, Cornell attempted to 'haunt' a cinema audience who were sitting down to watch an X-rated film. Before emerging from the shadows, Cornell draped himself in a white muslin sheet, the fabric covering him from head to toe. He then emerged before the unsuspecting audience and was bathed in the light of the projector. He moved in front of the screen, from the left-edge to the right-edge and back again.

Cornell, a Cambridge-based parapsychologist, was conducting experiments in "apparitional experiences." In his reports, he tacitly accepts the contentious premise that the spirits of the dead may literally walk among us as physical apparitions. His experiments did not directly address this question. Rather, he tried to artificially induce the experience of seeing 'real' ghosts, so that he could observe how people reacted to this unexpected and apparently paranormal experience.

Before getting back to that cinema, it's important to take Cornell's two preceding

experiments into account. Initially, he attempted to haunt a cow pasture near King's College. A four-and-a-half minute 'Ghost Walk' was carefully choreographed. He would crawl behind a small mound, wrap himself in a white sheet, and simulate appearing from nowhere by abruptly standing up. He would stroll to the next mound before vanishing by diving to the ground. Dress-rehearsals seemed to confirm that the appearances and disappearances were sudden and startling. Research assistants were stationed along the path to observe the unsuspecting passers-by. The stage was set. Six walks were conducted, but there was an unexpected complication. To Cornell's dismay, none of the approximately-80 by-passers gave any indication of having noticed anything at all. Cornell did note that the local cows appeared to regard him with rapt attention, perhaps as evidence to support his contention that he was clearly visible and in plain sight.

Reasoning that a more ghost-appropriate venue might lead to superior results, Cornell staged his next walks in the graveyard of St Peter's Church. Because the graveyard abutted a public road, the team took extra safety precautions. This time, Cornell's assistants were not merely standing by to observe; they were ready to step in to "avert any accident," which might result from onlookers being terrified and rendered "hysterical" by the 'Experimental Apparition' (which is how Cornell consistently refers to his bed-sheet-shrouded self). Such precautions proved unnecessary. Between pedestrians, cyclists, and motorists, Cornell estimated that approximately 142 people were in positions to witness the apparition, and of these, only four gave clear indications of having seen it. Under questioning, it emerged that none of them believed they had witnessed anything remotely paranormal. The first person described the apparition as "a man dressed as a woman, who surely must be mad" another assumed that it was "an art student walking about in a blanket." Two noticers, when questioned together, did realize that the Experimental Apparition was

probably *intended* to simulate a paranormal event, but went on to note that the effect was spoiled because “we could see his legs and feet and knew it was a man dressed in some white garment.”

This brings us back to the cinema, which Cornell argued was clearly the logical next step after the cow pasture and the graveyard. Still determined to induce a paranormal experience, he wrote that his next experiment needed to take into account two important considerations. His first consideration was a practical one: He wanted to present the Experimental Apparition in a place where the spectators would be focusing their attention. In this respect, the preceding peripheral hauntings were clearly suboptimal. His second consideration was an ethical one: Cornell wrote that he had grown concerned about the potential for the Experimental Apparition to traumatize children. He worried that, if the apparition did convincingly simulate a real haunting, it could potentially be terrifying to young viewers. He specifically selected an X-rated film to “safeguard” against the risk that children might be frightened. He made arrangements to conduct his Ghost Walk during the trailers preceding the feature. The Experimental Apparition was clearly visible for approximately 50 seconds as it passed in front of the screen. Six research assistants, distributed about the audience, monitored the proceedings. Before the feature film started, Cornell sans bed-sheet, re-emerged with a microphone to survey the crowd.

For Cornell, the experiment was another failure. None of the audience reported anything remotely paranormal. Many saw nothing unusual at all: 46% of the respondents had failed to notice the Experimental Apparition when Cornell first passed in front of the screen, and 32% remained completely unaware of it. Even the projectionist, whose job was to watch for anything unusual, reported that he had completely failed to notice the apparition. Those that did see ‘something’ were not particularly accurate in their descriptions. One person reported having seen a fault in

the projector, another saw a woman in a coat, yet another claimed they had seen a polar bear. Of the entire audience, only one person accurately described what had been presented: a man dressed in a sheet pretending to be a ghost. Cornell ultimately concluded that such failures to see should be attributed to an absence of a “subtle psi-factor” or “telepathic stimulation” that would normally correspond with a ‘genuine’ haunting. He went so far as to suggest that the number of ‘true’ hauntings may actually be grossly under-reported.

While Cornell’s psi-based conclusions would be largely unwelcome in a contemporary scientific journal, his *results* fit excellently into a modern research framework. Watching the trailers can be conceptualized as the audience’s primary task, similar to discriminating between crosses or counting basketball passes. And Cornell’s pseudo-ghostly bedsheet-clad-self served as a critical stimulus rather than a simple shape or even a gorilla costume. In fact, Cornell’s experimental paradigm, with the critical stimulus occurring live in front of participants, rather than on a computer monitor, makes his one of the few experimental studies to demonstrate inattentional blindness for a real object or event occurring ‘live’ at fixation. Despite the fact that the experiment is highly unconventional, and was not designed to investigate human visual attention, the results can nevertheless inform our understanding on inattentional blindness phenomena. Ironically, I think there is a robust argument to be made for the reverse of Cornell’s conclusion that his findings suggest that ghost sightings and hauntings are under-reported. Cornell’s project can be considered as example of a metacognitive illusion. The fact that many people failed to detect the Experimental Apparition can be understood in terms of inattentional blindness, but the results are nevertheless surprising and counterintuitive to anyone unfamiliar with that particular psychological explanation. Even today, a many people

claim to have seen ghosts. A recent YouGov (2014) poll reported that 34% of the British public have witnessed a ghost, and the Pew Research center (2009), found that 29% of Americans claim to have 'been in touch with the dead.' Perhaps these numbers can at least partially attributed to people experiencing perfectly natural perceptual illusions that they do not believe are possible.

2.6. Inattentional Blindness in Hugo Münsterberg's

Classroom Demonstration of Eyewitness Testimony (1907)

The only other such recorded instance of inattentional blindness for a centrally presented live stimulus actually occurred even *earlier* than Cornell's publication of his experimental apparition paradigm. The study in question was reported by Professor Hugo Münsterberg, and while Münsterberg did identify himself as a psychologist, his study, like Cornell's and Haines' experiments, was not published in a psychology journal. Instead his experiment was informally reported in the general audience monthly periodical *McClure's Magazine* in 1907, and it was later re-published as part of Münsterberg's popular psychology book *On the Witness Stand*. Appropriately, the general thrust of Münsterberg's article and his subsequent book was the idea that people's perceptual experiences are not as accurate and vivid as we might think they are: a phenomenon that, today, may be referred to as a failure of visual metacognition. Münsterberg was particularly concerned with how this issue related to real-world legal problems involving eye-witness testimony. Münsterberg wrote that the legal professionals had dangerously false ideas about the psychology of perception and memory. He developed a classroom demonstration to illustrate how fallible such testimony could actually be. The experiment was only briefly presented and did not constitute what a contemporary researcher would consider a formal

write-up, but nevertheless it does provide a fascinatingly prescient description of what we might now consider to be the phenomenon of inattentional blindness:

I stood on the platform behind a low desk and begged the men to watch and to describe everything which I was going to do from one given signal to another. As soon as the signal was given, I lifted with my right hand a little revolving wheel with a colour-disc and made it run and change its color, and all the time, while I kept the little instrument at the height of my head, I turned my eyes eagerly toward it. While this was going on, up to the closing signal, I took with my left hand, at first, a pencil from my vest-pocket and wrote something at the desk; then I took my watch out and laid it on the table; then I took a silver cigarette-box from my pocket, opened it, took a cigarette out of it, closed it with a loud click, and returned it to my pocket; and then came the ending signal. The results showed that eighteen of the hundred had not noticed anything of all that I was doing with my left hand. Pencil and watch and cigarettes had simply not existed for them. The mere fact that I myself seemed to give all my attention to the colour-wheel had evidently inhibited in them the impressions of the other side. Yet I had made my movements of the left arm so ostentatiously, and I had beforehand so earnestly insisted that they ought to watch every single movement, that I hardly expected to make any one overlook the larger part of my actions. It showed that the medium, famous for her slate tricks, was right when she asserted that as soon as she succeeded in turning the attention of her client to the slate in her hand, he would not notice if an elephant should pass behind her through the room. (Münsterberg, 1907, p. 135)

In summary, Münsterberg instructed a lecture hall filled with students to “watch everything and describe everything” that he was about to do. He then held up a mechanical color wheel in one hand and stared at it. While continuing to stare at the wheel, he used his other hand to produce a series of objects from his pockets. When he collected students’ written reports of his actions, eighteen out of the hundred students failed to give any indication of any of the additional objects in their testimony of the events. This experiment fits less neatly into the framework of a modern-day inattention paradigm than the studies presented above- Münsterberg’s paradigm involved multiple critical stimuli that were not distinct from his participants’ explicit primary task of ‘watching everything.’ However, it is arguably still worthy of consideration as an early demonstration of inattentional blindness (Simons, 2011; Wiseman & Watt, 2015). Münsterberg’s experiment can be

conceptualized as being similar to a full attention trial with multiple unexpected critical stimuli. His participants were explicitly told to ‘watch everything’ rather than being instructed to perform a specific primary task. We now know that participants may adhere to implicit task parameters even when such parameters contradict explicit primary task instructions (Aimola Davies, Waterman, White, & Davies 2013). Once again, we can see an example of a metacognitive error on the part of the investigator. Even though he presumably developed the experiment to illustrate the unreliability of eye-witness testimony, Münsterberg’s brief description clearly reveals that he was caught off-guard by the results. He wrote that “he hardly expected to make anyone overlook the larger part of [his] actions.” He concluded by making a somewhat dramatic reference to the misdirection skills of fraudulent spiritualist mediums. Citing an un-named slate writing practitioner, he asserted that a skilled performer could direct an audience’s attention in such a way as to render even an elephant invisible.

2.7. Inattentional Blindness for Magic Trick Methods (1887)

Münsterberg’s reference to fraudulent spiritual mediums is particularly apposite given that his is the topic of the final and earliest study to be considered in this chapter. Hodgson and Davey’s (1887) report, titled “The Possibilities of Mal-Observation and Lapse of Memory from a Practical Point of View” (subsequently referred to as “The Mal-Observation Report”) pre-dates Mack and Rock’s (1998) book by more than a century.

Neither of the authors of the Mal-Observation Report would have considered themselves to be experimental psychologists. In 1887, the discipline of ‘experimental psychology’ was only beginning to garner recognition as an independent scientific discipline through the popularization of work from figures like William James at

Harvard and Wilhelm Wundt at Leipzig. Hodgson and Davey were ‘psychical researchers,’ investigators of paranormal phenomena including manifestations of dead spirits through spirit mediums. In particular, they were interested in fraudulent mediumship. They wanted to explore how participants in séances could be deceived into thinking they had witnessed supernatural events when they had really seen something that might be more accurately described as a magic trick.

Richard Hodgson (1855-1905), was born in Melbourne, Australia and obtained a degree in Law from Cambridge University (Baird, 1949). During his time at Cambridge, Hodgson befriended Prof. Henry Sidgwick and joined the recently formed Society for Psychical Research (SPR), a group of scholars who had formally banded together in 1882, with the goal of scientifically investigating phenomena associated with the budding spiritualist movement. Members included scientific luminaries like Alfred Russell Wallace (1896), William Crookes (1874), and Oliver Lodge (e.g. Wallace, 1896; Crookes, 1874; Lodge, 1909; see Chapter 2 for a more detailed discussion of the relationship between early psychological and psychical research practices). Hodgson made his reputation as a talented detective debunker of spiritualist mediums. He led the SPR’s first major investigation into spiritualism. He travelled to India to investigate Countess Helena Petrova de Blavatsky, a Russian occultist who had attracted a significant following based on her alleged supernatural abilities. She claimed that she was channelling the spiritual the teachings of dead mystics. She also claimed that she could project her body into an ‘astral form.’ Hodgson spent two months in India attempting to verify Blavatsky’s claims. In his eventual report, which he published through the SPR in 1885, he declared that the phenomena that she claimed credit for were entirely fraudulent. The letters she claimed to receive from spirits of the dead were written in her own hand, and the

spirit forms she took, were simply her human accomplices wearing disguises. He argued that her followers were “excessively credulous and deficient in observation,” and that she was actually the center of a “huge fraudulent system.” The Blavatsky investigation was arguably what sparked Hodgson’s interest in the relationship between magic tricks and eye-witness testimony.



*Figure 2.2. A Portrait of Richard Hodgson
(from Carrington, 1931)*

In order to conduct the experiments described in the Mal-Observation Report, Hodgson teamed up with an amateur magician: SJ Davey. Before he began practicing magic, Davey was a true believer in the reality of spiritualist phenomena. He wrote that he initially came to his beliefs after seeing a recently deceased friend in a dream. He was further inspired after reading an English translation of Zöllner’s *Transcendental Physics* (1881), and personally witnessing the apparently miraculous talents of the spirit medium William Eglington. Davey was particularly fascinated by the phenomenon of ‘psychography’ also known as slate writing (e.g. Oxon/Moses, 1882). This was a process whereby mediums could apparently obtain messages from the spirits of the dead. In a typical example, the medium might invite a séance participant (a.k.a. ‘a sitter’) to direct a question to the spirits. The medium would then present the sitter with a pair of chalk writing slates, of the kind that were

common in classrooms at the time. The medium would clearly show that the slates were free of writing. The medium would then openly produce a small piece of chalk, then arrange the slates on the table so that one was resting atop the other, with the piece of chalk sandwiched between them. The miracle would occur when the medium, who might not have even appeared to have touched the slates, would reveal that a message had appeared written on the previously blank slate. The exact nature of the message varied between different mediums and individual circumstances- for example, the message might be short and specific or lengthy and vague, and it might be written across multiple slates or multiple sides of slates. In each case however, the message, which was apparently dissociated from any worldly agency, would be attributed to spirits. Such demonstrations and the testimony of people who witnessed the demonstrations were considered to be empirical evidence that spirits of the dead could interact with the physical world of the living (e.g., Conan Doyle, 1927; Wallace, 1875; Zöllner, 1881). In the introduction to the Mal-Observation Report, Davey revealed that, for a time, he actually came to believe that he himself possessed genuine supernatural talents. He experimented in trying to receive messages from spirits using slates, by leaving blank slates in locked drawers in his house. He was astonished upon examining some of the slates to find that messages had appeared on the slates that he himself had cleaned and locked away. Eventually, he came to realize that his friends were hoaxing him. And after he began studying conjuring, he was able to recognize that many of the effects that he had previously considered to be miraculous were actually attributable to magic trick methods. Davey eventually progressed beyond academic curiosity about magic and began putting his knowledge into practice.

The Mal-Observation Report represents the synthesis of Davey's conjuring expertise and Hodgson's first-hand experience debunking professional mediums. The report is not written as a formal research article, but rather describes a series of fake séances. Over the course of several months, Hodgson and Davey would invite various members of the public to attend séances hosted by Davey. Most, but not all of the séances took place in Davey's home. Occasionally, in order to conceal his identity as an amateur magician Davey would resort to various pseudonyms. All the séances were loosely scripted and would vary between different audiences as Davey improvised around individual circumstances and reactions. However, at the start of each performance, he would always specifically caution his audience to be mindful of any form of trickery or deception. However, he would not specifically tell them that he was going to be presenting magic tricks, nor did he ever explicitly attribute his performance to supernatural powers. At the conclusion of each séance, audience members were asked to provide written accounts in the form of letters, describing everything that they had experienced.

In total, the Mal-Observation Report collects 27 distinct accounts from 17 separate performances. Each account was reproduced in full and was accompanied by commentary from Hodgson and Davey about some of the key ways that the sitters' reports of the events deviated from the actual events. The sitters who reported that they had witnessed supernatural phenomena committed predictable and systematic errors in their reports. The reports typically omitted crucial elements of the séances—specifically elements that were instrumental for the accomplishment of the conjuring tricks. For example, in one of the scripted segments of the séance Davey would surreptitiously switch a blank slate for another slate that had been pre-marked with writing before the sitting began. Davey conducted most of his performances while

seated at a table. He would begin by showing the blank slate clearly; he would then place the slate under the table where he would switch it for the slate that had writing on it. He would then remove the slate with writing on it under the table, and, without revealing the writing to the sitters, he would feign disappointment that no spirits had been in contact. Then he would place the pre-written slate on top the table (writing side down) and ask the sitter(s) to place their hands upon it. After a brief time, he would then ask them to turn over the slate, revealing the writing, which he would pretend had just appeared while the sitters' hands were on the slate. The trick was only effective because he was able to place the blank slate under the table and replace it with the pre-written one. But the sitters' reports consistently failed to mention that the slate had been placed beneath the table. These omissions created a powerful illusion of impossibility for the sitters, and anyone reading their reports alone would have been unable to reconstruct the true method behind the trick. The Mal-Observation Reports' documentation of these omissions is very similar to the idea of inattentional blindness. Davey's actions were clearly visible and in plain sight of the sitters, and yet their belief that the writing was produced while they held the slates and their omission of the action of placing the slate under the table indicates that sitters nonetheless failed to detect these significant actions. The fact that sitters were instructed to watch his actions closely and clearly believed they had done so, suggest that, at least in some instances, their failures to detect the secret methods may have been related to having their attention otherwise engaged. However, given the fact that the reports were collected some time after the critical events, and participants were never specifically questioned about the critical events, it is not possible to definitively distinguish between online failures of awareness and subsequent failures of memory.

When considered from a contemporary perspective, the Mal-Observation Report arguably anticipates recent studies that have explicitly related magicians' misdirection techniques to inattentional blindness (e.g., Barnhardt & Goldinger, 2014; Kuhn & Tatler, 2005; Kuhn et al. 2008). In addition, Hodgson and Davey's discussion of misdirection induced false memories anticipated subsequent cognitive psychology research on reconstructive memory (Barlett, 1932) and misinformation effects (e.g. Loftus, 2005).

Reactions to the Mal-Observation Report, following its publication, also indicate robust failures of metacognition in some of its readers. One of the sitters who participated in Davey's performance was Alfred Russell Wallace, who, at the time, was something of a scientific celebrity, having recently co-discovered the theory of evolution with Charles Darwin. After sitting through a séance with Davey, Wallace had been utterly convinced that he had witnessed genuine supernatural phenomena. After the Mal-Observation Report was published, and Hodgson and Davey had explicitly written that they had been using magic trick methods, Wallace remained convinced that the séance had been supernatural. He wrote an angry letter to the SPR stating that Hodgson and Davey were engaged in a deliberate cover-up of Davey's mediumistic talents (Wallace, 1891). Wallace believed that the errors in the testimonies were impossibly extensive, and that his and the other sitters' perceptions must have been more accurate than they really were. He called on Hodgson and Davey to more fully reveal all of the methods that had been used in the séance. Davey resisted publishing all of his methods. He worried that knowledge of the specific methods that he used would potentially lead other investigators to be overly confident when attempting to debunk professional mediums, and that if people interested in fraud read the methods they could adapt their own performance

methods to be even more deceptive. Furthermore, he wished to continue conducting eye-witness experiments using the same methods that had been used in the Mal-Observation Report.

Sadly, Davey did not have the opportunity to conduct further research. He died of typhoid in 1891 at the age of 27 (“Obituary,” 1891). Shortly after Davey’s death, Hodgson acceded to Wallace’s demand and published a follow-up article, titled *Mr. Davey’s Imitations by Conjuring of Phenomena Sometimes Attributed to Spirit Agency* (1891). Hodgson provided additional details about the methods that Davey had used in the séances, including the choreography of the slate switching, and the fact that Davey had used a small ‘thimble writer’ a piece of chalk that he secretly affixed to his finger, in order to surreptitiously mark the slates during his performances. He also cited three key texts that contained instructions on how to perform the tricks that Davey had presented. The works referenced included Professor Hoffmann’s *Modern Magic* and *More Magic* (Lewis, 1876; 1890), Truesdell’s *The Bottom Facts Concerning the Science of Spiritualism* (1883), and the anonymously authored *Revelations of a Spirit Medium* (1882).

Interestingly, Richard Hodgson did not maintain his skepticism of spiritual phenomena in the years after the publication of the Mal-Observation Report. On the contrary, by the end of his life he had fully embraced the idea that the spirits of the dead lived on for eternity and could make direct contact with the living world. The psychologist William James was arguably responsible for Hodgson’s dramatic conversion. Hodgson had moved to Boston in 1887, in order to help establish a new US-based version of the SPR, the American Society for Psychical Research (ASPR). William James was one of the founding members of the ASPR, whose membership initially included other prominent American psychologists like Joseph Jastrow and

G. Stanley Hall. Although better known today for his iconic writings on psychology (e.g. James, 1890, quoted in the opening of this chapter), James remained open to the possibility of genuine psychical phenomena (e.g. Coon, 1992; Sommer, 2012). Moreover, he believed that he had discovered at least one *genuine* spiritual medium, a Bostonian woman named Leonora Piper. In a speech delivered to the ASPR in 1896, James argued that it would only take one genuine medium to legitimize the scientific possibility of the survival of the human soul after death. He noted that: “If you wish to upset the law that all crows are black, you mustn’t seek to show that no crows are; it is enough if you prove one single crow to be white” (p. 884) and declared that Leonora Piper represented his ‘white crow.’

After James introduced Hodgson to Leonora Piper in 1887, Hodgson went on to devote the final years of his life to the study of her mediumship (Baird, 1949; Berger, 1988). Piper claimed that she could enter into a special trance state, in which she was able to receive psychic messages from particular ‘spirit guides,’ including a French physician named ‘Phinuit.’ Hodgson came to believe that in some instances, when Ms Piper entered her trance, the spirit guides would take control of her voice, and at other times they would take control of her hand so that they could write messages (see Hyslop, 1905 for a credulous account and Gardner, 1995 for a skeptical interpretation). When in a trance, Ms. Piper would refer to herself as ‘the Machine’, and sitters who wished to communicate with the spirits that she channelled were instructed to hold her hand up to their mouths and speak into it, as if she were a physical telephone. She would sometimes admonish sitters to speak more loudly into her hand, as if there were a ‘bad connection’ and they were communicating over a great distance. Hodgson was initially skeptical of Ms. Piper and hired private detectives to investigate her and learn how she might be secretly acquiring outside

information to use in her séances. After his investigations apparently failed to reveal Ms. Piper's fraudulent methods, and Hodgson had personally attended several convincing sittings, he eventually wrote that he believed her mediumship represented genuine evidence of the survival of the human soul beyond death (Hodgson, 1898). Hodgson was inspired to begin experimenting personally with direct spirit communication. In his lodgings in Boston he maintained a special room, where he believed he could be contacted by his dead friends and the spirit guides of Ms. Piper. He would allow no one else to enter the room, lest they disrupt particular "magnetic atmosphere" that facilitated his communications (Baird, 1949; Carrington, 1931; Figure 2.2). One of his friends wrote that Hodgson 'surrendered his life' to the direction of the spirits that he had been introduced to by Ms. Piper (DeW H., 1906), and another of his colleagues, the psychologist Morton Prince, lamented that Hodgson's relationship with Ms. Piper "wrecked" his "beautiful mind," and that upon his conversion to spiritualism, "all his critical faculty was lost; his sense of perspective and proportion went with it" (Prince, 1910; quoted in Hale, 1970, p. 324-325). Hodgson died suddenly in 1905 at the age of 50, collapsing over an apparent heart attack during a game of handball⁵ (Howe, 1906; Sidgewick, Piddington, Howe, 1907). Ms. Piper asserted that his spirit returned to her, and her claim was tested extensively by Amy Tanner and G. Stanley Hall, who attempted to communicate with

⁵ Somewhat surreally, the most thoroughly documented account of Hodgson's life is a biography published in 1949 by Alex Baird. A non-spiritualist reader might be tempted to interpret Hodgson's conversion to spiritualism and subsequent eccentricities through a lens of psychiatric disorder. But Baird, an unapologetic believer in the survival of the soul after death, celebrates Hodgson's conversion, secret magnet room and all, as a true revelation and a positive personal development. In fact, his biography of Hodgson does not conclude with Hodgson's physical death, but instead continues with accounts of subsequent communications allegedly originating from Hodgson's ghost.

Hodgson's spirit through her. They ultimately concluded that "what was present of him, if anything, was not only fragmentary but incredibly stupid, oblivious and changed" (Hall quoted in Tanner, 1910, p. xxi).

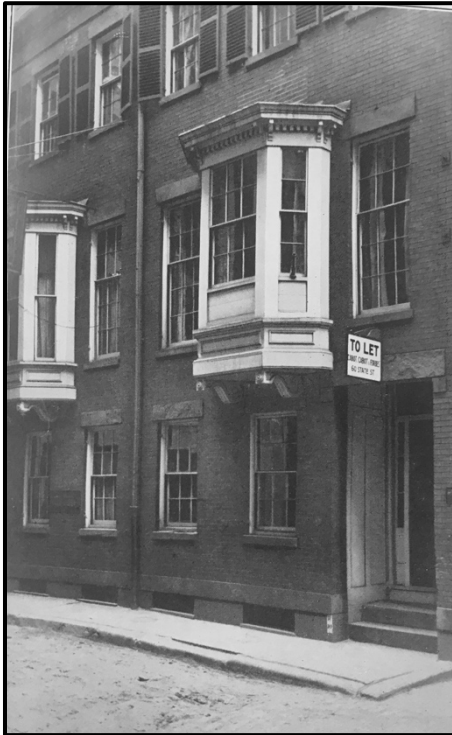


Figure 2.2. The site of Richard Hodgson's secret magnetic spirit communication room in Boston (photograph from Carrington, 1931)

2.8. Summary of Chapter 2: Ghosts of Gorillas Past

Descriptions of phenomena that seem very similar to inattention blindness can be seen in publications dating back to at least the late 1800's. When considered in the context of modern developments in cognitive psychology, these descriptions can add to our understanding of relatively recent lines of research. Of particular interest is the fact that these earliest accounts (Hodgson & Davey, 1887; Münsterberg, 1907) were directly inspired by observations related to magic performances or conjuring. Understanding how these the methods of past researchers, and considering why these methods were overlooked for decades, can potentially provide contemporary researchers with valuable new perspectives to drive future research. In the final section of this chapter, I will illustrate this point by

describing a modern-day adaptation of Hugo Münsterberg's classroom demonstration experiment and discuss how this paradigm is relevant to contemporary research questions related to sustained inattention for centrally presented dynamic stimuli. In the following chapter will, further expand on this concept of drawing inspiration for current research from historical sources. Specifically, I will explore historical relationships between magicians, psychics, and psychologists shaped the development of experimental psychology as a scientific discipline, and how magic has recently re-emerged as a powerful tool for modern-day researchers.

2.9. A Replication of Hugo Münsterberg's (Unintentional) Inattentional Blindness Experiment

The term 'inattentional blindness' was first introduced by Mack and Rock (1999), whose ground-breaking series of experiments systematically demonstrated that people could fail to notice objects and events that were fully visible and in plain sight, if their attention was otherwise engaged. Mack and Rock's stimuli consisted of simple computerized displays, with the unexpected critical stimulus generally taking the form of a geometric shape. Subsequently, Simons and Chabris (1999), adapted Neisser's (1979) selective looking experiments in light of Mack and Rock's experiments. In the Basketball Game Paradigm, observers were charged with watching a recorded video of two teams of players passing a basketball; in this case the unexpected critical stimulus took the form of an additional actor in a gorilla costume who strolls through the ball players and is fully visible for 5 seconds during the 75 second video. Conceptually integrating the basketball task into the framework of an inattentional blindness paradigm was an important development: it demonstrated that inattentional blindness results could extend beyond simple computerized tasks to more 'real life' circumstances of a dynamic visual scene in the

form of live-action video. This suggests that inattentional blindness is a phenomenon that may extend beyond laboratory stimuli and into everyday life. However, very few experiments have been conducted using 'live' events as stimuli.

The vast majority of inattentional blindness research has involved stimuli that are presented on computer monitors; to date, only six papers have been published that have reported investigations of the role of inattentional blindness in participants' perceptions of live dynamic events, with a further two studies reporting investigations of simulated pedestrian behavior in semi-immersive (Schwebel et al. 2012) and immersive (Neider et al., 2010) virtual reality environments. Of these, only one experiment (Kuhn & Tatler, 2005) has involved a critical stimulus that was presented centrally, i.e. near the participants' fixation. The remaining seven examined participants' perceptions of stimuli that were presented continuously, but peripherally, i.e., objects or events that were displayed alongside a route that participants were walking. These experiments have shown that pedestrians can not only fail to notice inanimate objects such as sea shells, shoes (Nasar et al. 2008) or paper money (Hyman et al., 2014), but they can also be blind to clowns (Hyman et al., 2010; Chen, Saleh, & Pai, 2016) and simulated assaults (Chabris, 2011). Kuhn and Tatler's paradigm was based on a magic trick specifically developed to explore the relationship between magicians' misdirection techniques and inattentional blindness. They used misdirection to conceal the trick's method in plain sight. Participants watched a magician perform a trick where he apparently caused a cigarette and a lighter to disappear. The magician was seated across the table from the participant/spectator, and the 'vanish' was accomplished by dropping both the cigarette and lighter into his lap, where they were concealed by the edge of the table. When the cigarette was dropped, its fall was visible for an average of 140 milliseconds. Thus, the method was (briefly) fully visible and in plain sight of the

participants. Nonetheless, only 2 out of 20 participants detected the fall of the cigarette.

While it is not a formally documented experiment, there is one instance of an experimental psychologist demonstrating that participants can be inattentionally blind to live stimuli that are presented to them centrally and continuously. The demonstration in question was reported by the early experimental psychologist Hugo Münsterberg.

Hugo Münsterberg (1863-1916, Figure 2.2) was born in Prussia and began his academic career by studying medicine. He would shift his focus to Psychology after attending a lecture delivered by Wilhelm Wundt in 1883. Münsterberg spent several years working and training in Wundt's Laboratory as a research assistant. After completing his doctorate in physiological psychology in 1885, he moved on to the University of Freiberg to complete a medical degree. During his time at Freiberg, he helped establish Germany's second laboratory of experimental psychology (with Wundt's Leipzig Laboratory having been the first), and he began to achieve international recognition for his empirical investigations of perception, attention, and memory. In particular, his work captured the attention of William James, who would become instrumental in securing Münsterberg a position at Harvard University. Münsterberg took over James' position as the chair of Harvard's Psychological Laboratory. He arrived at Harvard in 1892 and by 1897 he was awarded a full professorship. Münsterberg remained at Harvard until his death 1916, when he actually passed away in the middle of giving a lecture (Münsterberg, 1922).

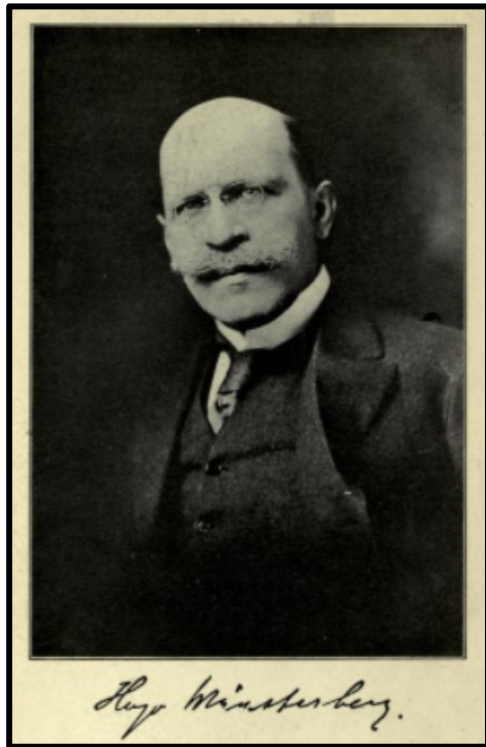


Figure 2.3. A portrait of Hugo Münsterberg, that appeared in his posthumous biography that was written by his wife, Margaret (Münsterberg, 1922).

During his years at Harvard,

Münsterberg became known as an outspoken and controversial figure. He served as one early evangelist of experimental psychology, working tirelessly to promote the nascent science to the public. In addition to his academic publications, he also wrote extensively for popular magazines. His efforts to establish psychology as an applied science, combined with his rigorous boundary work to distinguish psychology from psychical research would lead him into conflicts with both of his iconic mentors. In contrast to Wundt, who believed that experimental psychology ought to be developed as a more abstract ‘pure’ science, Münsterberg was eager to apply psychological research to practical problems including industrial/organization issues, education, and law (Bornstein & Penrod, 2008; Weiss & Xuan, 2015). Münsterberg would likewise diverge from James’ more philosophical brand of psychology by embracing more empirical lab-based approaches to psychological questions. James and Münsterberg would also clash on the subject of psychical research. James maintained an agnostic perspective regarding scientific questions about telepathy, clairvoyance, and survival after death, and he was strongly in favor of integrating

these questions into the domain of experimental psychology (e.g., Coon, 2002; Sommer, 2012). In addition to his tenure as president of the American Psychological Association, James also served as the president of the American Society for Psychical Research. During an address to the society, he publicly declared that he had personally encountered at least one genuine psychic medium: Leonora Piper. James referred to Ms. Piper as his “white crow”- noting that “If you wish to upset the law that all crows are black, you mustn’t seek to show that no crows are; it is enough if you prove one single crow to be white.” (James, 1896, p. 884). James would regularly visit Ms. Piper to communicate with his deceased mother. In contrast, Münsterberg was dogmatically opposed to psychical studies, arguing categorically that all questions of spiritualistic phenomena could be explained through fraud and misperception and that the field was unfit for scientific examination. He summarized the entire body of psychical research as being metaphorically equivalent to a “a vast desert of endless stupidity” (Münsterberg, 1899, p. 78).

It was Münsterberg’s interest in the application of experimental psychology to law combined with his interest in debunking psychical phenomena that would lead him to be interested in the study of eye-witness testimony. In 1907, he published an essay for *McClure’s Magazine*, in which he described a series of experiments intended to demonstrate the fallibility of eye-witness accounts. While the experiments he describes were not formally reported in any academic journal, one experiment in particular stands-out as being especially prescient of future investigations of inattentional blindness:

"I stood on the platform behind a low desk and begged the men to watch and to describe everything which I was going to do from one given signal to another. As soon as the signal was given, I lifted with my right hand a little revolving wheel with a colour-disc and made it run and change its color, and all the time, while I kept the little instrument at the height of my head, I turned my eyes eagerly toward it. While this was going on, up to the closing signal, I took with my left

hand, at first, a pencil from my vest-pocket and wrote something at the desk; then I took my watch out and laid it on the table; then I took a silver cigarette-box from my pocket, opened it, took a cigarette out of it, closed it with a loud click, and returned it to my pocket; and then came the ending signal. The results showed that eighteen of the hundred had not noticed anything of all that I was doing with my left hand. Pencil and watch and cigarettes had simply not existed for them. The mere fact that I myself seemed to give all my attention to the colour-wheel had evidently inhibited in them the impressions of the other side. Yet I had made my movements of the left arm so ostentatiously, and I had beforehand so earnestly insisted that they ought to watch every single movement, that I hardly expected to make any one overlook the larger part of my actions. It showed that the medium, famous for her slate tricks, was right when she asserted that as soon as she succeeded in turning the attention of her client to the slate in her hand, he would not notice if an elephant should pass behind her through the room." (Münsterberg, 1907, p. 135)

Given the fact that, in hindsight, this brief passage describes a conceptual precursor to contemporary inattentional blindness methodologies, I was interested in seeing whether Münsterberg's paradigm could be replicated in a modern classroom. Münsterberg specifically noted that he wished "to avoid all technicality," and these few hundred words comprise the entirety of his description of the experiment. Nevertheless, the above description contains enough detail to design a 21st century replication. My replication keeps to the gist of Münsterberg's demonstration, the most notable deviations being that several of the items, namely the mechanical color wheel, the pocket watch, and the cigarette case were replaced by items that were deemed to be more familiar to contemporary participants. Rather than a color wheel, my participants were shown an Android tablet with a 10-inch display that had been set to play a short video that caused the screen to display various colors and simple shapes. Instead of a pocket watch, my participants were shown a mobile phone (an iPhone 6s). In place of a cigarette case, a tin of mint Altoids was presented. The mint tin was selected because it was deemed to be less anomalous, in the context of a modern university lecture theatre, than a cigarette

case, and it was approximately the same shape and size. Additionally, it could be closed with a loud click, as Münsterberg describes doing with his cigarette case in the original experiment.

The current experiment was conducted in a lecture theatre with 101 participants (87 female, mean age 19.7 years), who self-reported as being neurologically healthy and having normal or corrected-to-normal vision. After obtaining informed consent, a paper questionnaire was distributed, which asked for participants' age and gender and included a blank space for them to describe what they saw during the experiment. The experimenter then verbally instructed the participants to "Watch and describe everything that I do, from when I say GO until I say STOP."

The experimenter stood at the front of the lecture theatre with a small table on his right-hand-side. The experimenter held up the tablet in his left hand, at head height with the display facing the participants. The experiment lasted for 80 seconds, during which the tablet displayed a simple video of shifting shapes and colors (see <https://youtu.be/nFPiBkD3PTg> for a copy of the video that was displayed on the tablet). Throughout the experiment, the experimenter's gaze remained fixed on the tablet's screen.

While the video played, the experimenter produced a series of three objects from his pockets using his right hand. After the video had played for 10 seconds, he produced a red pen from his inner left jacket pocket, scribbled randomly on a piece of paper on the desk to his right, and then set the pen down. After the video had played for 30 seconds, he reached into his right trouser pocket and produced a mobile phone (an iPhone 6s), which he set on the table. After 50 seconds, he produced a tin of mint Altoids from his outer right jacket pocket; he set the tin on the table, opened it, and removed a single mint, which was placed on the table. He then

closed the tin with a loud ‘click.’ The experimenter called “stop,” after the video had played for 80 seconds (see Figure 2.4, for depictions of the stimulus materials used).



Figure 2.4. The four objects used in the experiment, in order of presentation. A tablet computer (in place of a mechanical color wheel) was held aloft by the experimenter throughout the procedure. The experimenter produced a red pen, an iPhone (in place of a pocket watch), and a tin of mints (in place of a cigarette case).

Participants’ written responses indicated that 10% had failed to report *any* additional objects or actions of the experimenter’s right hand, 42% failed to report the presentation of the pen, 34% failed to report the presentation of the mobile phone, and 15% failed to report the presentation of the tin of mints (see Table 6.1 for a breakdown of the number of objects reported by participants). As with Münsterberg’s original experiment, participants were not asked explicitly about

additional objects, and their responses were analyzed based on whether they contained any mention of the objects. The current results are broadly in agreement with the original report: 11 out of my 101 participants were seemingly inattentionally blind to all the objects. My results also allow me to consider additional levels of detail unreported by Münsterberg; I was able to assess the reports of individual objects. While relatively few participants completely failed to report all the objects, 50% of them failed to report at least one of the objects.

Table 2.1.

Number of Objects Reported by Participants

Number of objects reported (Total 3)	Number of Participants (N= 101)
0	11 (10.6%)
1	18 (17.8%)
2	22 (21.8%)
3	50 (49.5%)

Overall, my results support Münsterberg’s contention that participants can fail to be aware of objects and events that are presented in plain sight. Considered through a modern lens, one might say that viewers can experience inattentional blindness to stimuli that are centrally presented in the context of a naturalistic dynamic scene.

This procedure was arguably different from a contemporary inattentional blindness experiments, in that the additional critical stimuli (the pen, phone, mints) were not irrelevant to the participants’ explicit primary task instructions. The instruction to watch “everything I do” is more methodologically similar to a full

attention trial rather than a critical trial of an IB experiment. This begs the question as to why participants might have exhibited such high rates of inattentive blindness for objects that were very clearly presented. Münsterberg himself suggests an explanation: that participants implicitly use the experimenter's gaze cue to define their task. In other words, because the experimenter keeps his gaze fixed on the tablet, some participants might assume that the task involves reporting the colors and shapes displayed on the device, rather than “everything” the experimenter does for the duration of the experiment. Modern research into social cues and gaze direction has shown that viewers will implicitly orient their attention in response to gaze cues (e.g. Nuku & Bekkering, 2008), this process has been demonstrated to be one element of magician's misdirection techniques (e.g. Kuhn & Tatler, 2006; Kuhn, Tatler, & Cole, 2009). Furthermore, other experiments have demonstrated that viewers will constrain their attentional set even in the absence of explicit task instructions, and that these implicit constraints can lead to increased rates of inattentive blindness (Aimola-Davies, Waterman, White, & Davies, 2013).

Overall, my attempt to replicate Münsterberg's experiment demonstrates that the paradigm he reported back at the turn of 20th century is largely a viable procedure for a modern inattentive blindness experiment. The concept of using a live classroom-based paradigm to collect data presents new opportunities for researchers who are interested in studying IB in beyond the constraints of a computer monitor. While I think it was an interesting exercise to try to adhere as closely as possible to the original methods, a number of improvements could be introduced in future experiments. For example, the instructions did not specify for participants exactly *when* during the procedure they should write down their responses, so it's possible that some participants could have been distracted during stimulus presentation by the act of writing. Additionally, if participants did believe

that the experiment involved focusing on tablet, it is possible that they could have noticed the additional objects during the experiment and failed to report them. This confound could be addressed by an additional follow-up question, along the lines of “During the course of the experiment, the experimenter held a tablet computer. Did you see any additional objects during the course of the experiment?”

In hindsight, this particular experiment clearly makes an important contribution to the field of perception research, Münsterberg’s book was arguably less successful at its stated goal of integrating experimental psychology with the actual practice of law. While Münsterberg’s book is sometimes cited as an example of one of the first attempts to apply experimental psychology to legal problems, European researchers had actually been conducting experiments on human testimony in the decades preceding Münsterberg’s work (see Sporer, 1982 for review). Not only did Münsterberg fail to fully acknowledge the previous work conducted by researchers like Binet (1897, 1900) and Stern (1902) but his book was written for a popular audience and presented in a style that was considered highly offensive to some contemporary legal scholars. For example, Münsterberg argued that legal professionals and scholars had “absurdly neglected” psychological research, and he accused them generally of “prejudice and ignorance” and “being slow to learn.” Rather than being inspired to embrace academic psychology, evidence suggest that most contemporary legal scholars who read the book were highly critical of Münsterberg’s relatively simplistic generalizations about criminal law (e.g. Wigmore, 1909). Overall the result of Münsterberg’s book was arguably to alienate legal scholars and professionals, setting back the integration of experimental psychology research from applied law by several decades in the English-speaking world (Sporer, 1982; Weiss & Xuan, 2015).

Chapter 3

Methods from Madness

A History of Magic in Science and Psychology



In the past 15 years, the scientific investigation of magic has undergone something of a renaissance. Since the year 2000, the body of experimental scientific literature on the topic of performance magic has more than quadrupled, in comparison to all of the experimental work published prior to the turn of the 21st century. A total of 55 empirical papers have been published on the topic between 2000 and 2017, compared to the 12 that were published in the preceding century, between 1887 and 1999 (see Figure 3.1). While the recent level of focus on the topic is arguably relatively novel, records of performance magic can be traced back to some of the oldest surviving written records. Additionally, the idea of investigating the psychology of magic actually played a key role in the emergence of experimental psychology itself during the late 1800s. Given the recent rise in interest in the psychology of magic it is important to look back on previous perspectives on the topic. This chapter will begin with a review of historical approaches to describing magic that predate to emergence of experimental psychology: beginning with a consideration of historical records of ancient Egyptians and Greeks, continuing on to medieval manuscripts. Next, I will examine role of magic in Victorian-era investigations of spiritualism, and how these investigations influenced the earliest psychologists as they were working to define the science of psychology⁶. I will demonstrate how these historical perspectives set the stage for recent Science of Magic ‘renaissance,’ and my own empirical work.

⁶ I have published portions of this chapter in the *New Scientist* under the title ‘Blinded by séance: The man who offered scientists an afterlife’ (Tompkins, 2017)

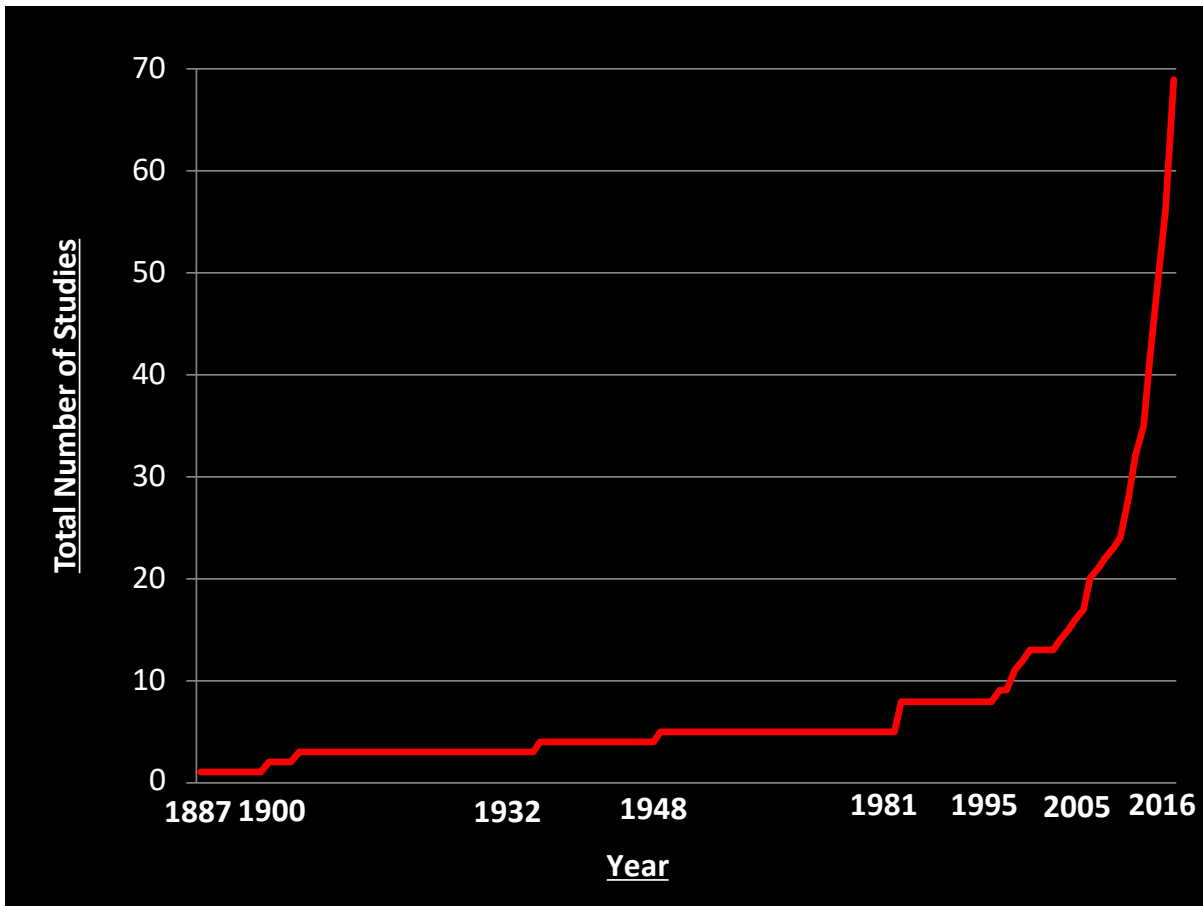


Figure 3.1. A depiction of empirical research on magic and magicians between 1887 and 2016. (See Appendix A for a chronological list of the publications.)

3.1 Historical Accounts of Magic (18th Century BC – 1887): Gods, Witches, and Ghosts

The performance of magic can be traced back throughout recorded history.

Generally, what would be considered magical performances by modern standards were often presented to early societies in the context of religious rituals and mystical rites (e.g., Gregory, 1982). Such historical accounts are complicated by the fact that ancients did not always distinguish clearly between historical records and legends. Magic, religion, science, and medicine were sometimes inexorably interwoven. While magic tricks were often presented as pure entertainment, they were also presented as evidence of divine or supernatural prowess. The earliest written descriptions of such performances can be traced to at least the 18th century BC, specifically, to hieroglyphs

translated from excavated fragments of ancient Egyptian papyrus (Mackenzie, 1907).



Figure 3.2. The Westcar Papyrus is currently displayed in the Ägyptisches Museum, Berlin. (Photo by Schengili-Roberts, 2006)

The Westcar Papyrus seems to have been written around the time of the Thirteenth Dynasty, sometime between 1803 and 1649 BC. It describes events that took place during the Fourth Dynasty, 2613 to 2494 BC. Specifically, it depicts stories of a priest, Djedi, who performed impossible feats before the court of the Pharaoh Khufu. Djedi's performance included lion taming and decapitating birds only to magically restore them to life (Lichtheim, 1973). His actions are attributed to power bestowed by gods, and the stories contain other fantastical elements analogous to fairy tales (e.g. Ritner, 1993). Nonetheless, the papyrus does contain references to genuine historical figures—the Pharaoh Khufu was a real pharaoh who ordered the construction the Great Pyramids at Giza. While there are no other surviving records of the magician Djedi, it is possible that the stories originate from a real person who performed stage illusions (Christopher, 1973). This principle of presenting illusions as manifestations of divine powers is more explicitly substantiated by existing records from ancient Greece. The Greeks reportedly used complex mechanical stage illusions, not only as part of religious ceremonies, but also for entertainment

purposes (Gregory, 1982). For example, Heron of Alexandria (1st Century AD, translated by Woodcroft, 1851) wrote descriptions of elaborate mechanical devices developed to ‘magically’ open temple doors (Figure 3.3) and to apparently transpose water into wine in the context of religious ceremonies.

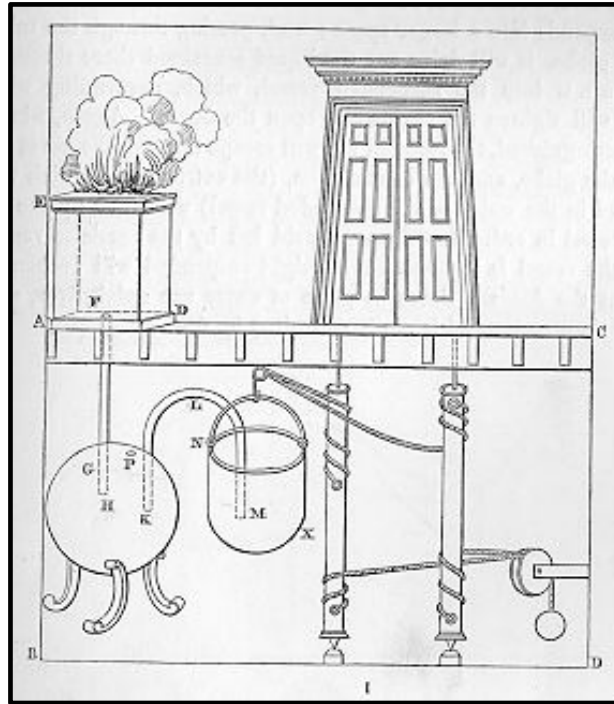


Figure 3.3. A schematic created by Heron of Alexandria that depicts a mechanism to open temple doors, apparently by magic (image from Woodcroft, 1851)

Heron also recorded schematics for an automaton wherein a figure appeared to pass a sword through the neck of a horse without damaging it. While these writings do have relevance to the modern concept of stage illusions, they are limited in that they merely describe the construction of mechanisms and offer very little indication of performances or presentations (Figure 3.4).

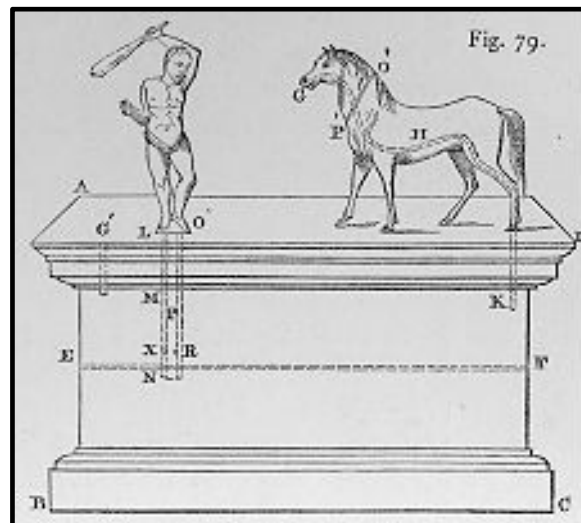


Figure 3.4. A schematic created by Heron of Alexandria that depicts an automaton where a figure apparently passes a knife through the neck of the horse, but (magically), the horse is then able to drink if water is presented to it (image from Woodcroft, 1851)

Other early writings relevant to the performance of magic tricks can be found in some medieval scientific manuscripts. For example, *Secretum Philosophorum* is a Latin text originating in England around the late 13th century. This book covers a variety of topics ranging from rhetoric and music to arithmetic and geometry. The third section of the manuscript titled ‘Dialectic’ is concerned with teaching readers to ‘discern between truth and falsehood’ and concerns itself with the ‘deception of the senses.’ The experiments detailed include optical tricks with mirrors and some juggling tricks that are very similar to conjuring tricks. Included is a description of how to apparently transform water into wine using dyes, how to create a ‘flash powder’ that ignites brightly but will not burn skin, and how to apparently levitate small objects by suspending them from fine (practically invisible) hairs. The *Secretum Philosophorum* also describes a version of a cut-and-restored rope trick (see Goudling, 2006, for a complete English translation of the Dialectic chapter).

While the accounts of magic discussed above describe magic effects and, in some cases the methods that can be used to accomplish them, they did describe any particulars on how to perform or present the tricks. One of the first written accounts to concern itself with magic performance beyond basic methods is the *De Viribus Quantitatis*, or *The Power of Numbers*. This book was written between 1496 and 1508 by Luca Pacioli, one of the tutors of Leonardo da Vinci. This book, written in Italian, contains advice on how to perform apparently extraordinary feats like appearing to douse one's hands in molten lead without being burned. It also contains what are, perhaps, the first ever written descriptions of card tricks. The manuscript as a whole not formally published at the time, but the sections of it relating to magic tricks were distributed as short printed pamphlets (Singmaster, 2008; Bossi, 2008).

The oldest known English written account of magic trick methods can be found in a small book titled *Naturall and Artificiall Conclusions*. The book was originally published in 1556, and the oldest surviving copy was printed in 1581 (Hall, 1972). Little is known about the listed author, Thomas Hill, a translator and compiler, whose other definite writing credits include a treatise on home gardening techniques (Considine, 2004). While the front matter of the book claims it was originally written by scholars of the University of Padua and 'Englished' by Thomas Hill, evidence suggests that the book was in fact written and compiled by Hill himself—the books contents are largely a compilation of other previously un-translated works (for example it contains a translated version of the water to wine trick described in the *Sectretum Philosophorum*) (Hall, 1972). The *Conclusions* are written as a popular scientific text, and they include techniques for how to kill fleas, breed farm animals, and compose folk medical remedies. This book also describes magic tricks to be presented as amusements. The methods are generally rather unsophisticated; for

example, Hill describes how to apparently magically ‘animate’ an apple by literally gluing it to a large beetle. Some of the methods described are also not physically possible, including a method for walking on water using round discs strapped to one’s shoes (Figure 3.5).



Figure 3.5. One of the less reliable tricks described by Hill (1556/1581). Hill falsely claimed that the apparatus pictured would allow the reader to stroll across the surface of water.

While several of the ‘experiments’ described by Hill can broadly be classified as magic tricks, the methods are relatively crude, and the explanations are interspersed with credulous descriptions of impossible phenomena- such as actual magical curses. In contrast, the first written English account of sleight-of-hand methodology was published in 1584 by Reginald Scot in a book titled *The Discoverie of Witchcraft*. In contrast to the ‘scientific’ tricks described in Hill’s *Conclusions*, Scot provides detailed sophisticated explanations for the methods and performance of a variety of magic tricks. Including basic sleight-of-hand-style conjuring tricks and stage-style tricks. Scot was a 16th century English judge who was seeking to debunk concept of

witches as being supernatural beings with extraordinary powers. Book 8, chapters 22- 34 are of particular interest. They pertain to sleight-of-hand, which Scot refers to as 'legierdemaine' or the 'art of juggling.'

Legierdemaine: the nimble conveiance of the hand, which is especiallie performed three waies. The first and principall consisteth in hiding and coneieing of balles, the second in the alteration of monie, the third in the shuffling of the cards... The conveieing of monie is not much inferior to the ball, but much easier to doo. (Scot, 1584, p. 182)

These sections of the *Discoverie* contain instructions for performing simple vanishes with balls and coins, as well as more elaborate stage illusions, such as appearing to decapitate and heal a man (a 16th century variation on a 'sawing a lady in half' trick, see Figure 3.6).

Scot had personally witnessed a particularly bloody period of witch trials in England, and he was likely inspired by the injustice of events like the trial and execution of Ursula Kemp (Howe, 2014). The overall thrust of the book is remarkably progressive, in that Scot consistently seeks to attribute naturalistic explanations for alleged supernatural phenomena⁷. It was, in fact, so progressive for its time that King James I is said to have ordered copies of the book burned out of fear that it would

⁷ Lamont (2016) asserts that the idea that earlier cultures were unable to distinguish between entertainment is overly simplistic. By way of illustration he notes that while King James wrote the *Demonologie* and presided over the execution of witches, James also apparently paid 'jugglers' to perform card tricks at his court. Nonetheless, I agree with Lamont's general point, however, I would argue that, just because people can be capable of distinguishing between magic tricks and supernatural witchcraft, does not mean that they are always successful. Nor do I believe these errors are confined to ancient/primitive superstitions. For example, Arthur Conan Doyle, argued passionately that the magician Harry Houdini possessed 4th dimensional super powers, despite Houdini's protestations (Doyle, 1930). Additionally, I have personally spoken to a contemporary magician, Wayne Houchin, who was attack and lit on fire on national television in while filming a magic special in the Dominican Republic in 2012. The host of the program, having witnessed Wayne's performances, concluded he was possessed by demons and tried to purge him with fire (Jones, 2012). Thanks to the quick action his crew, Wayne was quickly extinguished and rushed to a hospital where he was treated for burns on his head and face. He went on to make a full recovery and is back to performing.

cause readers to discount what he perceived to be genuine supernatural dangers⁸ (see Allmond, 2009 for a review of accounts of James burning *The Discoverie*). Scot's chapter on magic tricks arguably served as the definitive English text on sleight-of-hand until the publication of Professor Hoffman's *Modern Magic* in 1876 (Hall, 1972). The vast majority of magic texts published between 1584 and 1876 were entirely or at least partially plagiarized from Scot's writing.

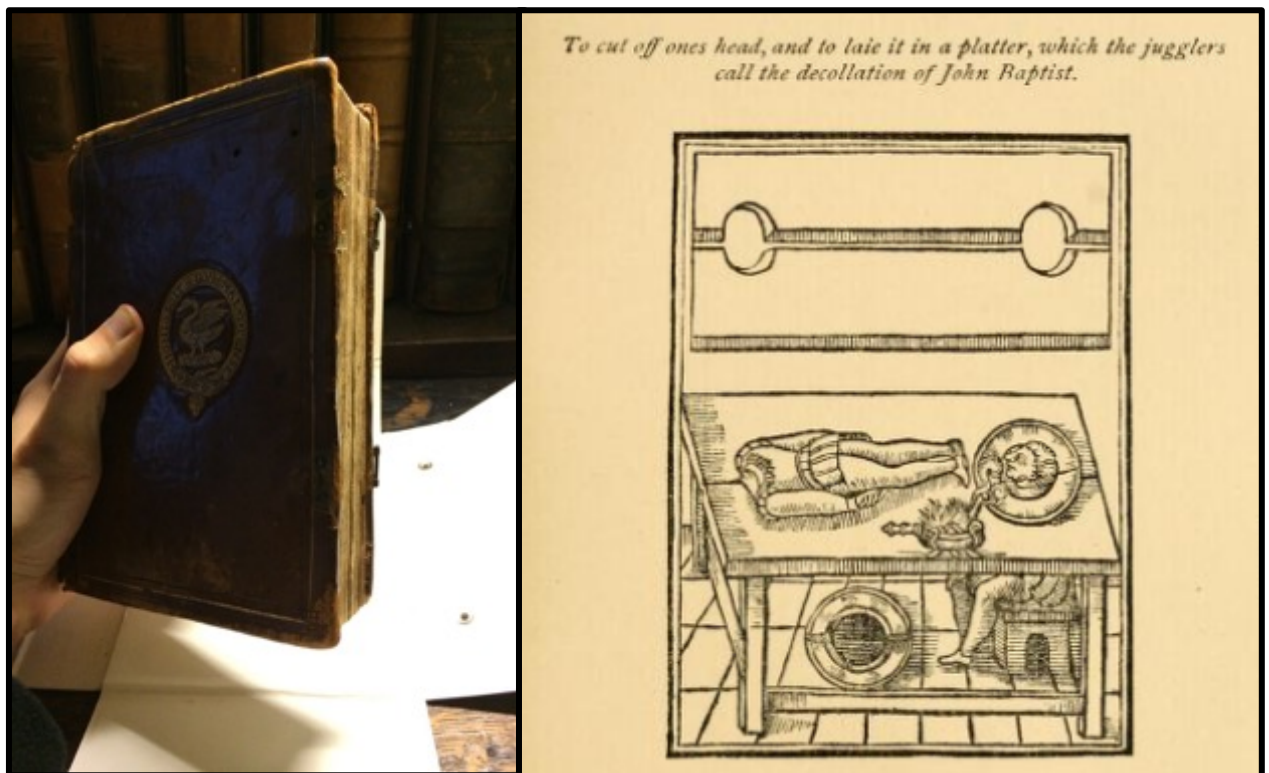


Figure 3.6. A first edition of Scot's (1584) *Discoverie* held by Oxford's Bodleian Library and an illustration of a decapitation illusion trick as explained by Scot (p. 294).

⁸ King James IV of Scotland who would go on to become James I of England, exhibited a profound hatred of witches. He is the only monarch in history to have written and published a treatise on witchcraft *The Daemonologie* (1597), which he wrote in direct opposition to Scot's more skeptical *Discoverie* (Thomas, 1971). James evidently believed that demons and witches represented a legitimate supernatural threat to his subjects, and thus opposed Scot's efforts to debunk them.

While the texts I have presented are not traditionally associated with psychological literature, together they provide a picture of how people throughout history have described and attempted to explain seemingly magic phenomena. These writings are prototypical examples of how people tried to approach the psychology of illusion. When experimental psychology eventually emerged as a scientific discipline in the later part of the 19th century these ideas of magic illusions and apparently impossible phenomena would be extremely important for early psychologists.

3.2 Psychology, Spiritualism, and the Wundt-Zöllner Debates

This concept of turning to magic trick methods to explain-away supernatural phenomena re-emerged into sharp focus around the turn of the 20th century. People at that time may have liked to think of themselves as being more skeptical of the concepts of demons and witches compared to Scot's (1584) readers, but many were swept up in the trend of 'spiritualism.' Spiritualism was based around the idea that the dead can communicate with the living through extraordinary individuals that serve as psychic 'mediums.' As a philosophical social movement that began in the mid-1800s and has continued into modern times, spiritualism involves a complex combination of influences and motivations. It has also been closely associated with religious reformations and various progressive causes, including abolitionism and women's rights. My considerations will focus on one particular facet— the assertion that spiritualist practitioners could *physically* demonstrate elements of their religious philosophy by presenting empirical evidence, that is to say measureable physical evidence, of supernatural phenomena: e.g. predicting the future, directly communicating with dead individuals, or otherwise violating conventional physical laws. Historically, systematic investigations of such spiritualist claims have resulted in uncovering mistakes or outright fraud (e.g., Houdini, 1924). These fraudulent

mediums are particularly relevant to the current discussion because they often used methods based on performance magic to accomplish their seemingly impossible feats.

Of particular relevance to psychologists interested in investigating the science of magic is the fact that some of the founders of experimental psychology, including Wilhelm Wundt, Gustav Fechner, Ernst Weber, William James, and G. Stanley Hall were all heavily involved with investigations of the physical phenomena of spiritualism. For experimental psychologists at least, I propose that the conflict between science and spiritualism can be traced to one particular Sunday afternoon, at precisely 3pm in Leipzig Germany, on 18th November 1877 (Zöllner, 1880). Throughout the next sections of this chapter, I will trace the development of spiritualism and explain how the empirical testing of spiritualist claims would come to be intimately intertwined with the development of experimental psychology- in particular Wilhelm Wundt's lab at Leipzig. In keeping with my theme of invisibility- these historical events have been largely overlooked by contemporary psychologists, but nonetheless they have interesting and important implications for current researchers interested in investigating the psychology of magic.

3.2.1 A select timeline of key events related to the Henry Slade's séances at Leipzig and the recognition of Wundt's Lab

The following outline highlights key events that will be discussed throughout the next section of this chapter relating to the relationship between spiritualism and experimental psychology.

- **Andrew Jackson Davis prophesizes a great spiritual awakening- 1847:** Davis predicts a great spiritual awakening in his best-selling *Principles of Nature* (Davis, 1847).
- **The Fox sisters allegedly contact a 'spirit entity'- 1848, March 31:**
 - The Fox Sisters allegedly make contact with a spiritual 'entity' in their house in Hydesville (Lewis, 1848).
- **The Fox sisters hold a public demonstration (and charge admission)- 1849, November 14:**
 - The Fox sisters give a paid public séance at Corinthian Hall (Capron & Baron, 1850).
- **Fechner experiments with a psychic medium- 1867, July 4:**
 - Fechner's examines an alleged 'sensitive.' He reports that she can apparently deflect a compass needle with her bare hand. (Original report reproduced in Zöllner, 1881)
- **Zöllner expresses his intention to empirically prove the existence of a fourth spatial dimension-1870:**
 - Zöllner speaks to the mathematician Felix Klein about the possibility of empirically demonstrating the existence of a fourth spatial dimension using 'impossible knots' (Klein, 1926).
- **Wundt begins teaching at Leipzig- 1875:**
 - Wundt takes up a post at the Philosophy Department of University of Leipzig (Bringmann, Balance, & Evans, 1975).
- **Henry Slade arrives in London: 1876, July 13:**
 - Slade arrives in London and begins conducting paid séances (Doyle, 1926).
- **Edwin Ray Lankester accuses Slade of fraud- 1876, Sep 16:**
 - Lankester writes a letter to *The Times* saying that Slade illegally defrauding the people who attend his séances (Lankester & Donkin, 1876).
- **First day of Slade's trial- 1876, Oct 2:**
 - Slade's trial begins at Bow Street Court in London. ("The Prosecution of Dr. Slade," 1876)
- **Conclusion of Slade's trial- 1876, October 31:**
 - Slade is convicted of fraud under the Vagrancy Act and sentenced to 3 months of prison and hard labor ("The Slade Prosecution," 1876)
- **Slade's conviction is dismissed- 1877, Jan 29:**
 - Slade's conviction overturned on appeal due to a technical legal issue. The original prosecutors move to arrange a re-trial ("The Slade Prosecution," 1877). Slade flees England before the re-trial can take place.
- **Slade arrives in Germany- 1877, November:**
 - He conducts séances in Berlin and secures an invitation from Zöllner to travel to Leipzig. (Marshall and Wendt, 1980)
- **Slade Meets Zöllner -1877, 16 November:**

- After arriving in Leipzig the previous day, Slade is invited to tea with Zöllner, Fechner, and Weber. At Zöllner's request, Slade demonstrates that he can deflect a compass needle with his bare hands. (Zöllner, 1881)
- **Wundt Attends One of Slade's Séances- 1877, 18 November:**
 - At Zöllner's invitation, Wundt and Thriesch attend a séance with Slade. Zöllner is not present, but writes an account based on Thriesch's recollections. Slade demonstrates slate writing, and apparently levitates a pocket knife. (Zöllner, 1881)
- **Zöllner publishes an article titled "On Space in Four Dimensions"- April 1878:**
 - Zöllner publishes an article in the *British Quarterly Journal of Science* describing how Slade has produced impossible knots (Zöllner, 1878).
- **Zöllner publishes two volumes of *Scientific Papers* detailing further experiments with Slade- Spring 1878:**
 - Zöllner publishes more than 2000 pages of his *Wissenschaftliche Abhandlungen (Scientific Papers)*, most of the content relates to his work with Slade. Although he also spends some time criticizing German universities, the press, and Jews. (Treitel, 2002; Sommer, 2014)
- **Ulrici challenges Wundt to explain Slade's powers- 1878:**
 - Hermann Ulrici publishes an article in *Zeitschrift für Philosophie und philosophische Kritik*. Based on accounts Zöllner's account of his experiments with Slade, Ulrici asserts that spiritualist phenomena represent an important new scientific question. He calls out all the witnesses of Slade's phenomena by name, including Wundt, and challenges them to provide a non-spiritualistic explanation or to endorse spiritualism 'by their silence.' (Ulrici, 1878).
- **Wundt publicly suggests that Slade is using trickery-1879, May:**
 - Wundt publishes an open letter, addressed to Ulrici. He suggests that Slade's powers might be attributable to 'jugglery' (sleight-of-hand), and questions the value of spiritualistic explanations (Wundt, 1879)
- **Zöllner publishes a third volume of *Scientific Papers* along with an open letter attacking Wundt-1879, October:**
 - Zöllner publishes a third volume of his 'Scientific Papers.' He details further experiments with Slade and details and proposes a new branch of science called *Transcendentale Physik*. He prefaces the book with an angry open letter addressed to Wundt (Zöllner, 1879).
- **Massey compiles Zöllner's experiments with Slade- 1880**
 - Charles Carleton Massey, and British barrister and proponent of Slade, collects Zöllner's key experiments from his *Scientific Papers* and publishes them in English, under the title *Transcendental Physics*. (Zöllner, 1980)
- **Wundt fails to secure an annual budget for his lab- 1882, April:**
 - Wundt petitions Leipzig for a regular budget to support his laboratory research. His petition is rejected (Bringmann, Bringmann, & Unger, 1980)
- **Zöllner dies- 1882, April 25:**
 - Zöllner dies suddenly and unexpectedly, at the age of 48. He collapses in the middle of having breakfast with his mother. (Hermann, 2008; Doyle, 1926)

- **Wundt assumes control of Zöllner's university budget- 1883:**
 - Wundt is made head of the commission tasked of recruiting a replacement to fill Zöllner's academic position. Wundt recommends that a replacement not be appointed, and uses the saved budget to establish a regular fund for his laboratory (Kohls & Benedikter, 2010).
- **Wundt's lab is formally recognized by the university-1883:**
 - Wundt's "Institute of Experimental Psychology" is formally recognized by Leipzig University (Bringmann, Bringmann, & Unger, 1980).
- **Henry Slade demonstrates slate writing for the Seybert Commission- 1885:**
 - Back in the USA, Slade accepted an invitation to travel to the University Philadelphia to demonstrate his powers (Doyle, 1926; Pepper et al., 1887).
- **George S. Fullerton travels to Leipzig to interview the surviving witnesses of Zöllner's experiments- 1886, June-July:**
 - He speaks to Wundt, Scheibner, Weber, and Fechner (Pepper et al., 1887)
- **Publication of the Seybert Commission Report- 1887**
 - The report indicated that Slade's powers were the result of trickery and that Zöllner had been of 'unsound mind' (Pepper et al., 1887).
- **Margaret Fox publically confesses to fraud- 1888, Oct 21:**
 - Margaret gave a public confession and demonstration of her trick methods on stage at the New York Academy of Music. A description of the event was published in *The New York World* the following day (Davenport, 1888).

3.2.2 The Emergence of Modern Spiritualism: Andrew Jackson Davis and the Fox Sisters

To understand how Slade came to Leipzig, it is useful to consider the historical context of the spiritualist movement. Spiritualism was a pseudo-religious movement that emerged from the United States in the mid-1800s (e.g. Doyle, 1926; Ferguson, 1933; Horowitz, 2010; Lamont, 2013). The groundwork had been laid by a staggering variety of religious 'awakenings' that took place around New York State. The region known as the 'Burned Over District' featured a steady eclectic parade of Doomsday cults, prophets, seers, and saviors. Some of the movements would develop into what are now relatively mainstream Christian sects, such as Mormonism and the Church of the Latter-Day Saints. Spiritualism was notable in that it effectively synthesized an

alternative Christian movement with emerging scientific and pseudo-scientific concepts.

Of particular note is the prophet Andrew Jackson Davis (1826-1910, Figure 3.7), known as the Seer of Poughkeepsie. Davis was a prolific author who claimed that he was able to travel psychically by projecting his consciousness across space and time. He claimed, for example, to have met the ancient Greek physician Galen ‘in person’ and studied medicine with him.

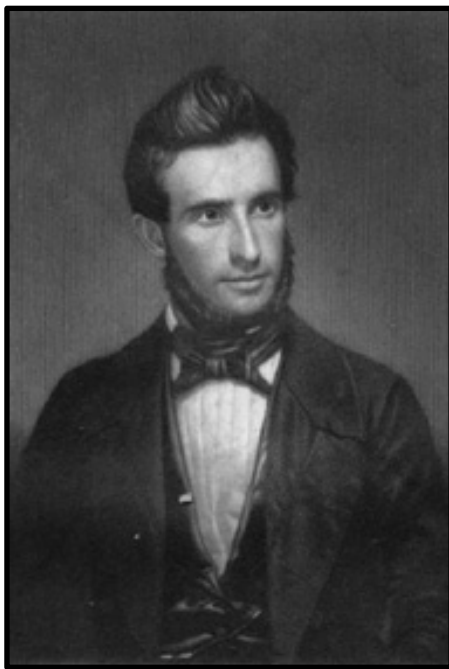


Figure 3.7. Portrait of Andrew Jackson Davis from 1887 (Public Domain image via Wikimedia Commons)

Davis’ writings, particularly *The Principles of Nature* (1847), which he claimed to have dictated from a mesmeric trance (Figure 3.8), captured international attention. In this book he presented a new philosophy, which was inspired by the Christian mystic Swedenborg, whose spirit Davis claimed to be in direct contact with. Davis had a somewhat mixed record as a prophet. He did make a number of surprisingly accurate predictions such as the emergence of mechanical typewriters, and personal cars powered by internal combustion engines. He also credited with having

accurately predicted that there were two additional planets in the solar system (before Neptune and Pluto were officially discovered). On the other hand, he was less correct about a number of details, like the round headed psychic residents of the planet Saturn and his “fact” that animal life could be spontaneously generated by heating chalk dust inside a hermetically sealed jar (Davis, 1925). Davis’ books nevertheless became international best sellers with *Principles of Nature* selling more than 900 copies within the first week of its publication, with four separate printings being necessary within its first year (“Have just received the Principles of Nature,” 1848). In 1847, Davis published a prophecy which stated that, in the next year, there would be a breakthrough between the spiritual dimension and earth. He wrote that:

The truth [of direct spiritual communication] will ere long present itself in the form of a living demonstration. And all the world will hail with delight ushering in of that era when the interiors of man will be opened, and the spiritual communion will be established such as it is now being enjoyed by the inhabitants of Mars, Jupiter, and Saturn, because of their superior refinement (Davis, 1847, p. 676-677).

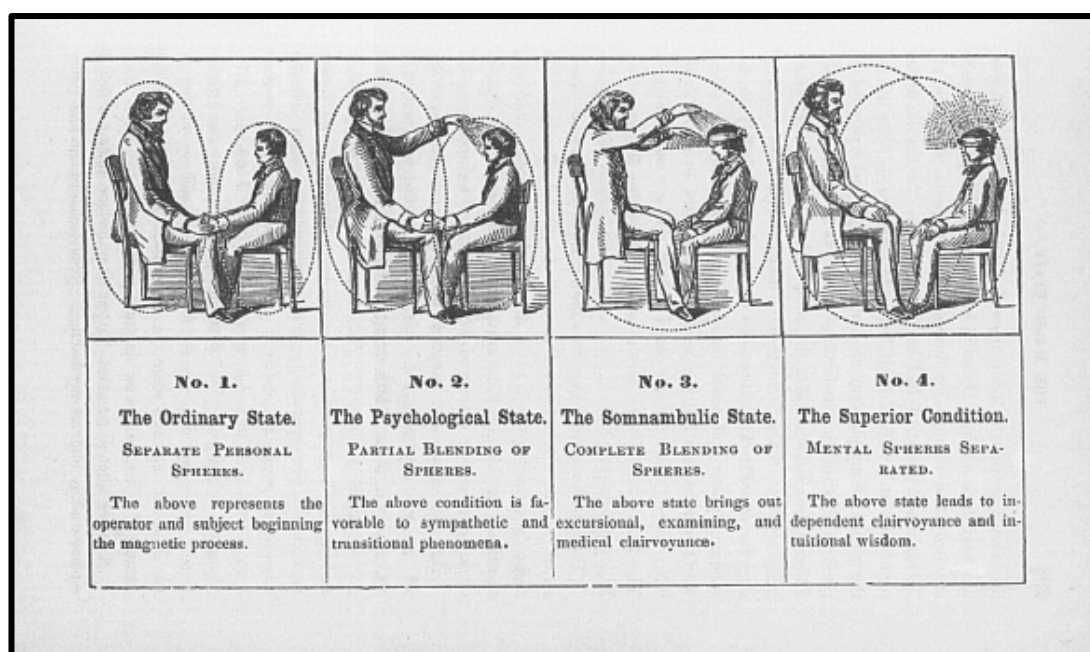


Figure 3.8. Andrew Jackson Davis’ explanations of mesmeric states (from Davis, 1857)

The popularity of Davis' writing and the timing of his prediction regarding the onset of a new spiritual era may have contributed to the subsequent attention that would be brought to bear on events in Hydesville, New York in the following year in 1848. A contemporary report, compiled by collecting witness statements of local residents (Lewis, 1848), strongly suggests that people believed that the spirit of a dead man did indeed make contact, just as Davis had foretold. The events in question took place in the house of John D. Fox, and specifically concerned his young daughters, Catherine (called Kate, age 11) and Margaretta (called Maggie age 14). The girls claimed to be woken at night by mysterious tapping noises, and neither their parents nor their neighbors could determine the source of the noises despite extensive searches of the house. The turning point came on the night of the 31st of March 1848, when Kate, addressing the 'entity' as "Mr. Splitfoot," struck up a conversation of sorts, establishing a communication method where the entity would knock out responses to simple questions. By this method, the family was able to determine that 'Mr. Splitfoot' was actually the spirit of a dead peddler by the name of Charles B. Rosna who had been murdered and buried in the basement. After their mother became convinced of the veracity of the spirit communication, the girls went on to demonstrate their method to their curious neighbors (Cadwallander, 1917; Lewis, 1848; Weisberg, 2004).

News of the Fox Sisters ability to communicate with the spirits of the dead spread quickly, first to the local community and then beyond. Mr. E.E. Lewis interviewed the Fox family and their neighbours and published a pamphlet titled *A Report of the Mysterious Noises Heard in the House of John D. Fox*, which would come to be internationally circulated. Further 'experimentation' indicated that the girls were

able to communicate with a variety of spirits. The next major development in the Fox Sisters' story occurred when their older sister Leah, aged 35 (Figure 3.9), arranged for Maggie to travel to Rochester and demonstrate her powers. The demonstration was held in Corinthian Hall on November 4, 1849 (Capron & Barron, 1850). An advertisement in the Rochester *Daily Advertiser* on November 3, 1849, promoted the event ambiguously as being either a revelation of "new and startling developments or the exposure of one of the most cunningly devised and long-continued impositions ever practiced in this or any other community" (quoted in Weisberg, 2004). It was also pay-per-view. Like a magic show, but with no disclaimer that the demonstration would involve tricks or illusions. Admission was set at 25 cents or 50 cents for a gentleman and two ladies. The evening received somewhat mixed reviews- with a mixture of skeptical and credulous reactions to mysterious knockings. That being said, she played to a full house of four hundred (Weisberg, 2004). These events sparked a movement that would flourish internationally from the 1840s through the 1920s, and still exists in various forms today⁹

⁹ Throughout 2015-2017, I personally attended several formal séances conducted in London by the London Spiritualist Alliance and the College of Psychic Studies, both organizations that were founded in the late 1800's and are still going strong.

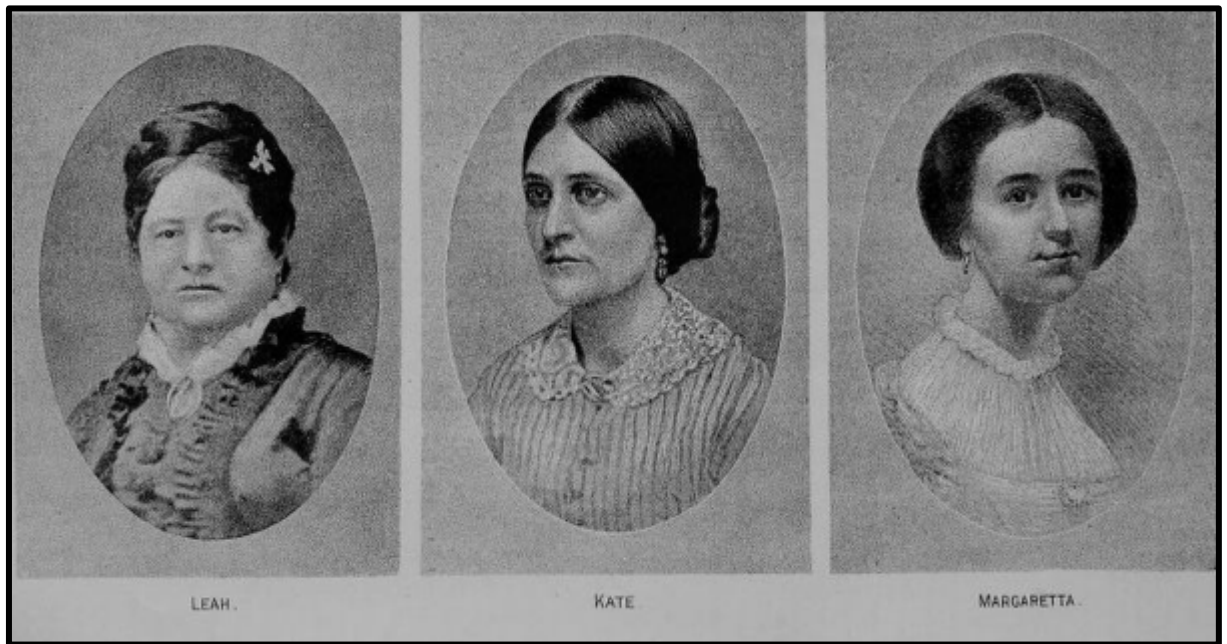


Figure 3.9. Portraits of each of the Fox Sisters (from Britten, 1884)

Despite their popularity, evidence *against* the Fox Sisters supernatural abilities was not in short supply. Looking back to the original events, there were no reports of missing persons within the community, certainly no one by the name of Charles B. Rosna (Nickell, 2008). Additionally, excavations of the basement failed to uncover any human remains, although, 50 years after the initial rapping, bones were allegedly ‘discovered’ in the basement. These were eventually to include chicken bone fragments that had been planted as a hoax (Nickell, 2008).

Perhaps the most compelling evidence against the spirit communications actually came Maggie Fox herself, albeit 40 years after the first reports. After having spent their adult lives working professionally as Spiritualist medium, Maggie set out to expose the methods behind what she now argued was as fraudulent practice. On the 21st of October 1888, Maggie took to the stage of the New York Academy of Music to publically confess her deception and describe the methods she had used to accomplish it. A description of her presentation along with a signed confession was

published the next day in the New York World (Davenport, 1888). Maggie explained that she and Kate had been the ones generating the first noises in her childhood home. The girls had actually used an apple tied to a piece of string. They would hang the apple beneath their bed and pull the string up and down, causing the apple to bounce off the floor and the bed frame. Margaret claimed that because she and Kate were so young, they were considered innocent of intentional deception. Later, under the management of their older sister, Leah, the sisters developed new means of generating 'spirit raps' including snapping the knuckle joints of their toes. Despite the press attention, these confessions appeared to do little to impede the spiritualist movement. Ironically, Margaret herself eventually went on to confess that her confession of fraud was, itself, fraudulent. And she tried unsuccessfully to return to being a professional medium, and once again asserting that she really did have genuine powers after all (Doyle, 1926; Weisberg, 2004).

3.2.3 The Trial of Henry Slade in London 1876

"Dr." Henry Slade (Figure 3.10) is a somewhat enigmatic historical figure. He was evidently a charismatic man, described by one New York Times reporter as having "a winning smile... and might be called handsome" ("Slade heard at last", 1880). His appearance was also recorded in detail by Horace Furnace, who stated:

I think Dr. Slade's personal appearance is noteworthy...He is probably six feet in height, with a figure of unusual symmetry, his hands are large but shapely... His face would, I think, attract notice anywhere for its uncommon beauty. He has a small, curling dark moustache, and short, crisp iron-grey hair, of a texture exceeding in fineness any that I have ever seen on a man's head. His eyes are dark, and the circles around them very dark, but their expression is painful. I could not divest myself of the feeling it was that of a hunted animal or of a haunted man. (quoted in Pepper et al., 1887, p. 80).

Many surviving records of Slade consist of duelling sets of ‘alternative facts’ from his supporters and detractors- leaving him as something of a cypher. Slade left his most significant marks on history by acting as a catalyst for explosive debates between scientists.



Figure 3.10. A portrait of the spirit medium ‘Dr.’ Henry Slade (Evans, 1897)

We do know that his title of Doctor was *not* derived from any medical or academic institution, but rather was adopted by him during his work as a ‘clairvoyant physician.’ He would travel about the US claiming to heal the sick by realigning their magnetic life forces. Slade’s breakthrough came when he began to advertise himself as a spirit medium (Figure 3.11). He claimed to be able to communicate with the spirits of the dead, and he would mostly receive these communications in the form of written messages that mysteriously appeared on slates.

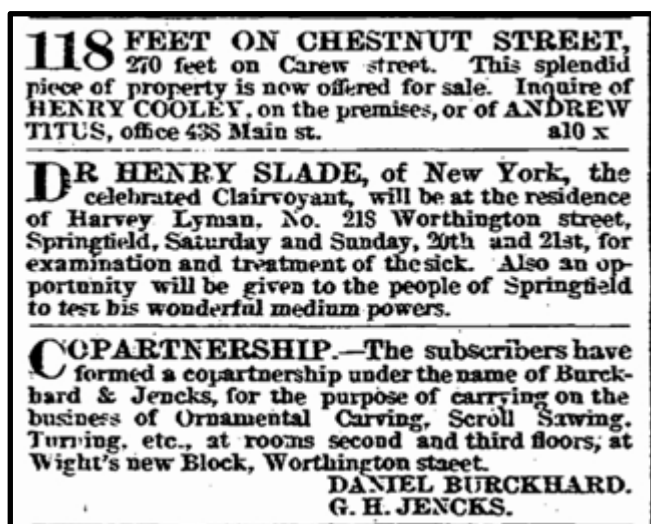


Figure 3.11. An advertisement for Henry Slade (rediscovered by Demerast, 2013) that appeared in the *Springfield Republican* on April 19, 1872.

After having established himself in America, Slade, allegedly accompanied by his deceased wife, Alcinda, embarked on a world tour to demonstrate his skills as a slate writing medium (e.g. Doyle, 1926). At his first stop in London he narrowly escaped being imprisoned for fraud. The sensational trial, which took place in the autumn of 1876, drew massive crowds and international media attention. Spiritualism sparked controversy by co-opting the language of scientific revolutions – leading to schisms, not only amongst the general population, but also in the scientific community. For example, Slade's trial pitted the two co-discoverers of the theory of evolution—Charles Darwin and Alfred Russel Wallace—against one another.

While the original court documents pertaining to the trial have been lost¹⁰, it is possible to reconstruct the events based on contemporary press accounts. Slade's prosecution was covered heavily by London newspapers including *The Times*, *The Daily Telegraph*, and *The Spectator*. After arriving in London, Slade immediately

¹⁰ I spent a long irritating day in the London Metropolitan Archives, poring over hand-written Victorian ledgers. The court documents were ultimately *not* where they were supposed to have been stored. The staff theorized that they might have been destroyed in flooding.

began his usual practice of holding his séances and was extremely popular with the locals. He was also visited by a young academic, Edwin Ray Lankester, who was a zoologist and a disciple of Charles Darwin and Thomas Huxley. Lankester, Darwin, and Huxley were strongly opposed to spiritualism on scientific and social grounds, believing that the credulity of some scientists who were investigating and endorsing spiritualism was damaging the reputation of science (Milner, 1999). While Charles Darwin himself did not personally attend Slade's trial, his letters to Lankester reveal that he congratulated the younger man on taking his case to court, and he even personally contributed 10 pounds (about 1000 pounds in today's currency) towards the cost of the court proceedings (Milner, 1996).

Lankester visited Slade twice, first on September 11, 1876. At this first meeting, Slade was able to produce written messages on his slates in response to Lankester's questions, and Slade also claimed to have produced mysterious lights (which Lankester claimed he had not seen). Among the questions Lankester posed to Slade was: 'Where was I last Saturday?' to which the 'spirits' eventually replied in the form of a slate message: "We did not see you last Saturday." This message was followed by the message: "We can write no more, we're tired." Lankester paid Slade one gold sovereign (about 100 pounds in today's currency) and arranged for a second séance. Their second meeting was held on September 15 and Lankester brought along his colleague Horatio Donkin. During this the second séance, Lankester interrupted Slade's performance and attempted to expose him as a fraud ("A Spirit Medium," 1876). The next day he and Donkin wrote a letter to *The Times* describing their experiences:

The real question to be investigated,” they wrote was “not ‘by what strange agency are these spiritualistic marvel brought about?’ but ‘How is it that apparently sane persons believe the spiritualists’ tricks are marvels due to a strange agency?’ The answer which all history gives to the latter question is to be found in the existence of an unexpended amount of credulity and incapacity for observation, and an unsuspected amount of impudence and mendacity. (Lankester & Donkin, 1876, p. 7)

Slade was arrested the following day (Milner, 1996).

Slade was charged under a British law called the Vagrancy Act of 1824, which had been originally written to give the police broad powers to arrest homeless individuals aka ‘rogues,’ including "unlicensed pedlars, fencers, jugglers, bearwards [bear keepers], minstrels, fortune tellers and gamesters", as well as "any persons wandering abroad in alehouses, barns, outhouses or in the open air, not giving a good account of themselves." The law was a direct evolution of 16th century Witchcraft Acts and crucially included a section to specifically target fortune tellers and astrologers, banning “every person pretending or professing to tell fortunes, or using any subtle craft, means, or device, by palmistry or otherwise, to deceive and impose on any of his Majesty's subjects” (“Prosecution of Dr. Slade”, 1876). Slade’s trial, which ran from October 2- October 31, proved to be quite sensational, featuring a diverse cast of characters, and a consistently packed courtroom. *The Times* complained that the atmosphere was not particularly dignified, noting that members of the public in attendance gave “audible utterances to their views on the evidence given. Indeed all attempts to suppress the applause or laughter were quite unheeded and at length abandoned as useless.” (“A Spirit Medium at Bow St.”, 1876).

The case rested on whether the prosecution could prove that Slade had set out to deliberately deceive Lankester and Donkin. The defense sought to prove that Slade was acting in good faith and genuinely *attempting* to conduct his séances honestly—

not that Slade was necessarily in possession of supernatural powers (“Prosecution of Dr. Slade,” 1876a).

The prosecution called John Nevil Maskelyne, as an expert in trickery and magic, to reproduce the ‘alleged phenomenon’ before the court (“Prosecution of Dr. Slade,” 1876b; “A Spirit Medium at Bow St.,” 1876). Maskelyne was something of a celebrity at the time, with a popular magic show regularly showing in London. True to his promise, Maskelyne appeared to produce impossible messages, including “THE SPIRITS ARE HERE” on ostensibly blank slates. He exposed various trick methods-e.g. discreetly writing with a piece of chalk that had been secretly affixed to his finger nail, using chemical fluids to apparently erase and restore writing on the slates, and composing messages by writing on the slates with a piece of chalk held in his mouth (which would be an effective way to produce mysterious messages in a dark séance room when one’s hands were bound). He maintained that all slate writing phenomena could be produced by conjuring, rather than by supernatural intervention. In particular, he also testified regarding a table that Slade had used during his séances with Lankester and others. Slade had specially commissioned a local carpenter to construct the table, shortly after his arrival in London. Maskelyne asserted that the table was designed in such a way as to facilitate conjuring tricks (see Figure 3.12). A prodigious showman and self-promoter, Maskelyne effectively dominated the proceedings for several days. Despite intermittent protests variously from both the presiding judge and Slade’s attorney’s, he used the trial as an opportunity to promote his ongoing show at Egyptian Hall. According to the newspapers’ accounts, Slade himself declined to produce slate writings for the court. He maintained that he did not perform under ‘challenge conditions’ asserting that ‘Allie’ considered such proceedings to be undignified (“Slade Prosecution,” 1976).



Figure 3.12. Slade's table, which was presented as evidence in his trial, is currently held by the London College of Psychic Studies. The inscription on the table reads: "This table produced in the case of Regina v. Slade and sworn to be a Trick Table by one John Nevil Maskelyne Conjuror a witness on behalf of Professor E. Ray Lankester F.R.S. before Mr. E. Flowers Magistrate at Bow Street Police Court October 1876."

Both Lankester and Donkin gave evidence as eyewitnesses, but although they both asserted that Slade was fraudulent, they were unable to explain how the writing had been produced. The crux of their case rested on the fact that Lankester had snatched a pair of slates from Slade's hands during the séance. Slade had just been explaining that his dead wife was going to produce writing on the blank slates, but when Lankester snatched them, it was clear that a message had already been written on the slates that Slade had, moments before, claimed to be blank.

Slade's defense included an illustrious cast of characters. Alfred Russel Wallace, the co-discoverer of the theory of evolution, spoke eloquently to the court in defense of the phenomena of spiritualism ("Mr. Wallace, the, Naturalist, Gave

Evidence,” 1876). Arthur Conan Doyle, the author of Sherlock Homes, did not personally attend the trial but met with Slade and wrote passionately in the mediums defense (e.g. Doyle, 1926). Slade’s attorney, Mr. Munton, crafted a particularly interesting argument. He acknowledged that Maskelyne was able to use conjuring to reproduce phenomena that resembled the supernatural phenomena that Slade claimed to have produced outside the court. However, he pointed out that just because Maskelyne was able to reproduce similar effects by trickery, it did not logically follow that Slade’s séances were necessarily conducted using similar methods, only that similar seeming results *could* be reproduced by a magician. In his concluding remarks, he appealed to the judge, arguing that all great men of science inevitably conflicted with the establishment, and explicitly compared Slade’s arrest for practicing slate writing to the church imprisoning Galileo for suggesting that the earth orbited the sun. He cautioned against judging Slade to be a fraud just because his practices conflicted with conventional ideas. “What was laughed at today” he remarked “might be very differently regarded tomorrow” (“The Slade Prosecution,” 1876). Munton did succeed in convincing the judge that Maskelyne’s testimony was irrelevant (“Prosecution of Slade,” 1876), but his arguments were failed to sway the judge’s ultimate verdict.

On November 1, Judge Flowers issued his verdict following 6 days of arguments (“Prosecution of Slade,” 1876). He opened by citing the Witchcraft Acts that served as the legal precursors for the current Vagrancy Act. Flowers confirmed that he did not consider Maskelyne’s tricks to be admissible evidence, but also indicated that testimony regarding Slade’s other, more successful séances was likewise irrelevant. He concluded that, on the weight of evidence, it appeared that Slade had written on slates himself, and therefore he had set out to deliberately

deceive Lankester and Donkin on the afternoon that they visited. Slade was convicted of “using any subtle craft, means, or device, by palmistry or otherwise, to deceive and impose on any of his Majesty's subjects.” Flowers sentenced Slade to 3 months imprisonment and hard labour.

However, that was not the end of the legal drama. Slade’s appeal of Flowers’ verdict was heard 3 months later, on January 29, 1877, at the Guildhall, Westminster. The ruling was overturned on a legal technicality (“The Prosecution of Dr. Slade,” 1877; “The Assistant Judge- Mr. Edlin,” 1877). Specifically, the prosecution had omitted the key phrase of the Vagrancy Act “by palmistry or otherwise” when they had initially filed their claim against Slade. Lankester quickly moved to arrange a second trial, but Slade left England for Europe before he could be arrested again. Slade never returned to England under his own name again (although he was identified many years later, in 1888, practicing slate writing under the false name ‘Mr. Wilson’ (Davey, 1888).

In the aftermath of the trial, Slade’s popularity amongst spiritualists was undiminished. The British Nationalist Association of Spiritualists published an open letter addressing the events of the trial- asserting that Slade was one of “the most valuable test mediums¹¹ now living” and noting that his reputation was undiminished by the conviction (Doyle, 1926). As years passed, Spiritualist believers would attest that Slade, rather than being freed on a legal technicality, had performed miracles before the court and had been released with an apology (e.g., Palmer, 1908). Such

¹¹ Spiritualists used the phrase ‘test medium’ to refer to mediums who they believed could reliability provide empirical scientific evidence of their powers.

accounts contrast sharply with contemporary newspaper reports. In any case, Slade's urgent departure from London set him on a collision course with some of history's most prominent psychophysicists and the Father of Experimental Psychology.

3.2.4 Séances at Leipzig

After fleeing England early in 1877, Slade travelled extensively throughout Europe, demonstrating his powers in France, Holland, and Denmark (Doyle, 1926). He began performing in Germany in Berlin, where he initially attempted to make contact with Hermann von Helmholtz, who was, at the time, one of Europe's most well-known and respected physicists in Europe. Helmholtz, however, was uninterested in becoming involved with spiritualism, and rebuffed him (Marshall & Wendt, 1980). Slade found a much warmer reception from another prominent German physicist: Johann Karl Freidrich Zöllner.

Zöllner held the chair of physical astronomy (what would be 'astrophysics' today) at Leipzig and had an established reputation as a physicist and experimentalist. He was well known throughout Germany at the time for his contributions to physics, astronomy, and philosophy. Prior to encountering Slade, he had invented various pieces of laboratory equipment, including a device called an astrophotometer that could be used to make measurements of distant stars (Kragh, 2012). He also, perhaps ironically, cultivated an interest in optical illusions (Zöllner, 1860; Figure 3.13). Significantly, Zöllner was also generally motivated by the idea of integrating idealized mathematical concepts with physical experiments. According to the mathematician Felix Klein (1927), Zöllner had expressed interest, as early as 1870, in the idea of empirically demonstrating the existence of a fourth spatial dimension. This was part of his motivation for developing an interest in the physical phenomena of spiritualism, especially after he discussed the idea of mediumship

with his colleague Gustav Fechner (Fechner's reports of his own spiritualist experiments are reproduced in Zöllner, 1980; see Felner & Lindgren, 2011 for English translations of Fechner's writings on the fourth dimension).

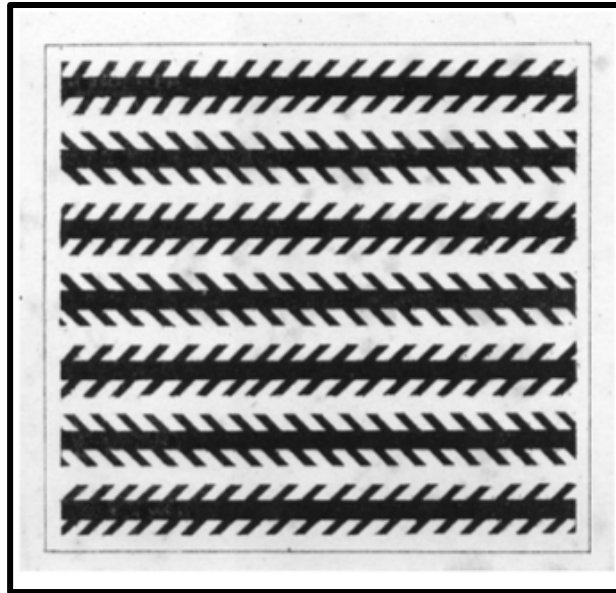


Figure 3.13. The Zöllner Illusion (Zöllner, 1860). The thicker horizontal lines are actually parallel, but smaller lines give the viewer the impression that they are not parallel.

Zöllner invited Slade to take tea with him on the 16th of November 1877. At Zöllner's request, Slade demonstrated that he could deflect a compass needle with his apparently empty hand (Zöllner, 1880). Zöllner was impressed, and he continued to test Slade's powers at a series of 30 sittings (or séances) that took place in Leipzig throughout the winter of 1877 and the Spring of 1878. Zöllner rushed to publish his findings and theories as a multi-volume set of *Wissenschaftliche Abhandlungen* (*Scientific Papers* published from 1877-1878), which contained more than more than 2000 pages describing his investigations of Slade. The writings stirred controversy not only in the Germany (e.g. Wolfram, 2009), but around the world. Zöllner also published selections of his papers in the British journal *The Quarterly Journal of*

Science in 1878, and in 1880 Charles Carleton Massesy, a British barrister, compiled and translated selections of Zöllner's papers and published them under the title *Transcendental Physics*—this book proved to be popular, particularly with English-speaking spiritualists, and was republished in multiple editions.

Throughout his papers, Zöllner maintained that his investigations of Slade, most of which he conducted in his own sitting room (Figure 3.14), took place under scientifically rigorous conditions. He himself variously referred to the sittings with Slade as experiments or séances. In his reports, he seemed to view himself as the lead investigator, while Slade was treated as both a collaborator and test subject (Figure 3.15). Crucially, Zöllner was aware of the accusations that Slade was dishonest. However, he wrote that Slade gave him “the impression of being a gentleman” (Zöllner, 1880, p. 21), and asserted that Slade was an honest man who was being unfairly slandered by small minded people. His investigations did not take a form might be considered a controlled psychological experiment today.



Figure 3.14. The sitting room in of Zöllner's home in Leipzig, where Slade conducted his demonstrations. (Image from Zöllner, 1879/1880)



Figure 3.15. Picture of Slade sitting with Zöllner (Willmann, 1897)

After his casual initial demonstration of deflecting the compass needle. Slade would also hold more 'formal' sittings- where Zöllner and his associates would sit with Slade in a circle holding hands. Sometimes, Zöllner would have particular test that he wished to carry out, sometimes he would simply wait to see what would happen. Slade himself maintained that he had not control over the phenomena, which merely occurred in his presence. Slade would often express surprise and disbelief at his 'results.' When Zöllner desired a particular test, he would ask Slade to 'ask his spirits.' Failures of the test were attributed to the spirits inability to understand what was asked of them. For example, in a séance that took place on the 9th of May 1878, Zöllner wanted to see if Slade's sprits could link two solid wooden

rings together, but instead he caused the solid matter of one ring to pass through the solid matter of the other. Slade agreed to try. Zöllner suspended the rings on a length of cat gut and hung them from a table where Slade was seated. While Slade attempted to link the rings, Zöllner noted that Slade's hands were visible on the table top, while the rings themselves were, for Zöllner, occluded by the table. After a few minutes, Zöllner heard a rattling noise in another part of the room (Figure 3. 16). When he investigated, he found that rings that had been hanging in front of Slade had apparently vanished and reappeared encircling the base of another small side table. The rings were not themselves linked. But because they had apparently passed through the surface of the side table, Zöllner declared the 'experiment' to be a success.

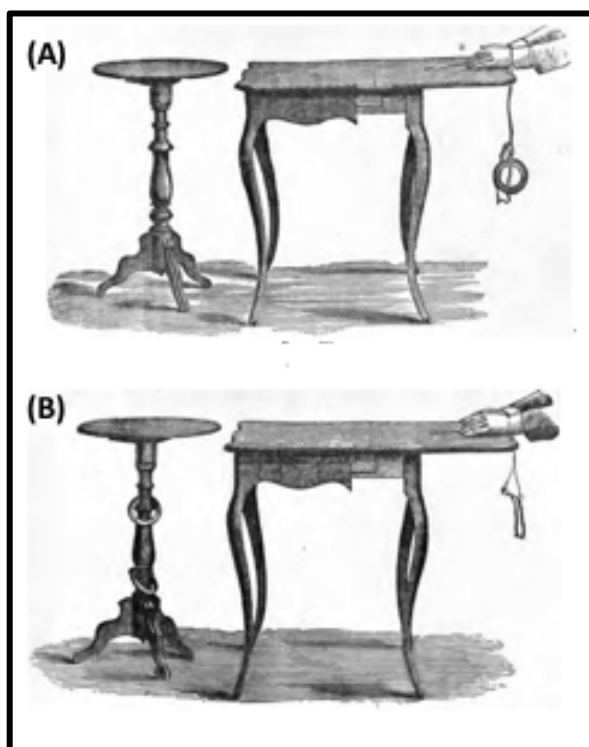


Figure 3.16. (A) A depiction of the set-up for Zöllner's ring linking 'experiment' and (B) A depiction of the 'results' with the rings having been mysteriously transposed to the nearby table (images from Zöllner, 1881)

Other seemingly supernatural occurrences included flickering lights, rapping noises, and disembodied music. Books and furniture might be flung about by mysterious forces. Objects, including coins, books, and furniture, would seem to flicker in and out of existence. During one sitting, on the 16th of November 1877, a bed screen that had been standing behind Slade cracked in half, a feat the physicists estimated would have required the strength of two horses. Shortly afterwards, the words “It was not our intention to do harm” mysteriously appeared on a slate that the scientists had cleaned themselves and would swear that Slade had not even touched. At another time, on the 11th of December 1878, a pocket knife (that was sitting apparently untouched on a table top) levitated violently into the air, it struck one of Zöllner’s visiting friends, a mathematics professor W. Schribner, directly in his face. The knife apparently left a lasting scar. There is no record of Schribner receiving an apology from the sprits. At other times, disembodied limbs appeared to form in the air around Slade. On the 15th of December, Zöllner saw a floating green hand appear in front of Slade (whose own hands were clearly visible). Zöllner reach out and seized the limb, which returned his grasp. Zöllner wrote that he “shook hands with a friend from another world.” (Zöllner, 1880, p. 217).

Zöllner believed that Slade’s feats represented empirical evidence of an otherwise unobservable *fourth* spatial dimension. A breakthrough that he would come to refer to as ‘Transcendental Physics.’ He theorized that the spirits of the dead, whom Slade claimed to contact, resided this extra-dimension, where they were unbound by our usual laws of three-dimensional space. Zöllner’s theoretical argument was actually quite sophisticated and partially derived from Helmholtz’s theories of unconscious inferences. In a series of lectures and publications presented

between 1868-1879, Helmholtz had suggested that three-dimensional perception is itself inferential, in that we extrapolate depth from information that falls on the flat surface of our retinas. By extension, he wrote, humans can conceive of a fourth spatial dimension (e.g. Helmholtz, 1878; see Stromberg, 1989 for review). One way of grasping this concept is through a thought experiment. We can imagine what a world might look like for beings who can only view two dimensions. This analogy was central to Edwin Abbott's (1894) novella, *Flatland*. We can imagine 2-dimensional beings, or flatlanders, who perceive only the edges of other two-dimensional shapes. If one were to introduce a third dimension, i.e. to lift a shape *up* off the surface of flatland, the results would appear to be impossible from flatlanders' 2-dimensional perspective. It would appear that the object had just passed from existence to non-existence. Similarly, anyone capable of viewing flatland from a three-dimensional spatial perspective would be effectively omniscient from the perspective of the flatlanders. Such an 'extra'-dimensional being, looking down on flatland, would be able to see *inside* of occluded surfaces (Figure 3.17).

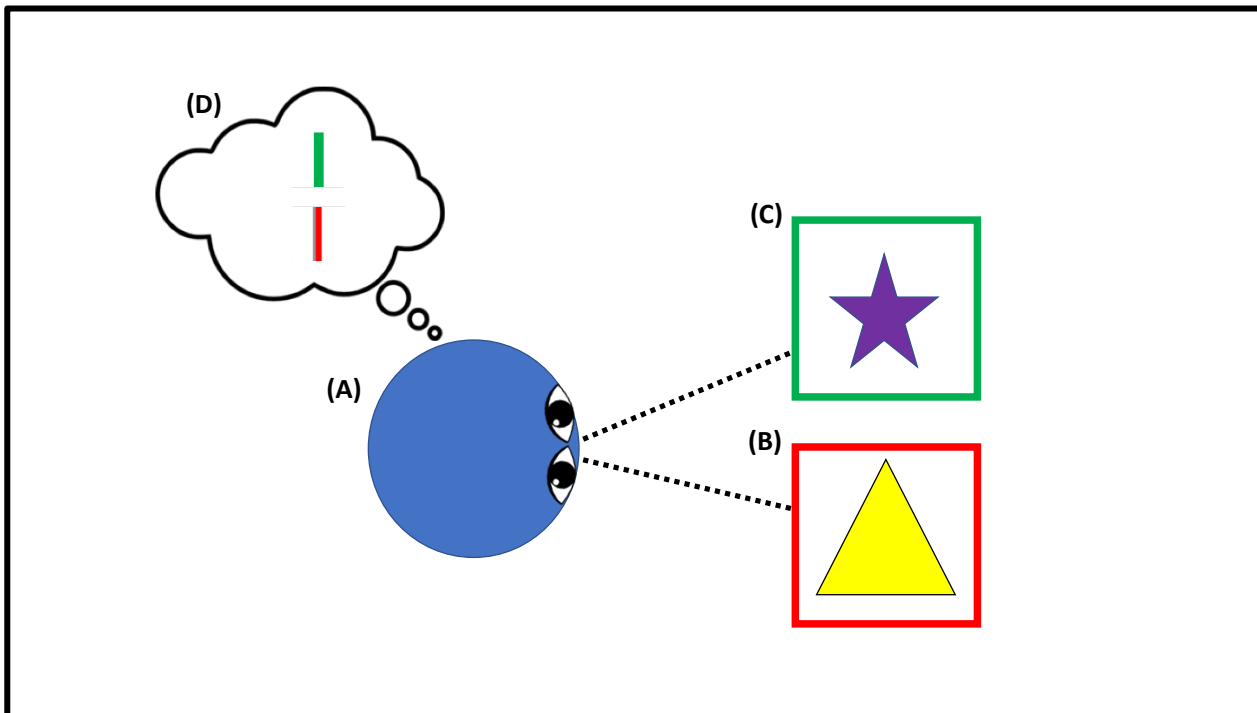


Figure 3.17. An illustration of a ‘Flatland’-style thought experiment. Imagine this two-dimensional illustration represents a two-dimensional ‘world.’ The flatlander (A) perceives this world in two dimensions. From the flatlander’s perspective, the objects (C & D) that it is looking at appear to be two lines, colored red and green. For purposes of this illustration, you, the reader, are an extra-dimensional being. You can perceive this world from an additional (3rd) dimensional perspective. From your extra-dimensional viewpoint, you can see that the objects (C & D) are actually boxes containing additional shapes that are invisible to the flatlander. Zöllner argued that Slade’s ‘clairvoyance’ represented a similar extra-dimensional perspective, except that in Slade’s case he was seeing things from an extra-fourth dimensional view point.

We can now extend this analogy to get an idea about perception in a fourth spatial dimensional. To us, as three-dimensional beings, four-dimensional spatial entities would be as seemingly inexplicable as three-dimensional spatial entities would be to a flatlander. Helmholtz had used this idea to illustrate a concept, but Zöllner took things a major step further – he claimed that Slade’s accomplishments were empirical proof of intervention from a fourth spatial dimension. How else could knots be tied into a rope without free ends, if not by rotating the middle of the rope into a fourth spatial dimensional – allowing solid matter to apparently pass through

solid matter? How else could Slade determine the date on a coin that was locked in a box under a table, if not by looking *inside* of the box from a four-dimensional perspective. Similarly, when the table seemed to vanish, it had simply rotated into the fourth dimension. Zöllner further argued that the spirits of the dead inhabited this fourth dimension; these were the entities that were contacted by powerful spirit mediums. Up until that last leap of logic, the hypothesis of a fourth spatial dimension actually offers a rather elegant explanation of many of the physical phenomena that occurred in Slade's presence. But, it was almost entirely reliant on Zöllner's assertion that Slade was an honest gentleman, who had no intention of deceiving the scientists.

Wundt's Open Letter on Spiritualism

Of all the men who would witness Slade in action during his time in Leipzig, only one would publically accuse him of dishonesty (Wundt, 1879, Figure 3.18). At the time, Wilhelm Wundt, was one of the University of Leipzig's newer faculty members (having been appointed in 1875). He hadn't yet managed to get the university to provide him with laboratory space, and he was struggling to run experiments out of his own apartment (Marshall & Wendt, 1980).

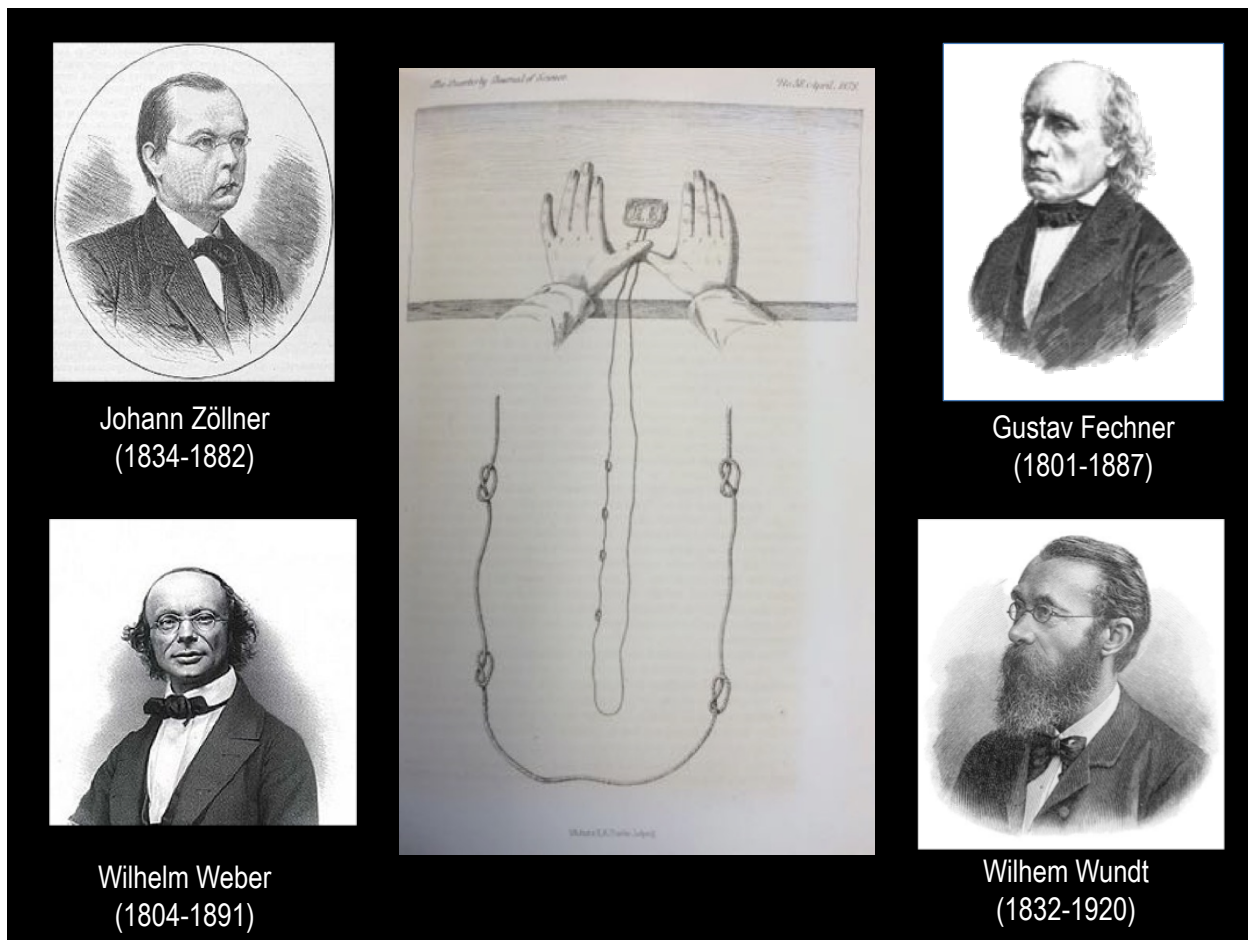


Figure 3.18. Some key witnesses to Slade's Leipzig séances. (Portraits are Public Domain images via Wikimedia Commons, and the depiction of impossible knots is from Zöllner, 1878)

Wundt only attended one séance with Slade. As mentioned already in the second paragraph of this section (3.2), he sat with the medium on Sunday 18 November 1877 at 3pm in the afternoon (Zöllner, 1880, Figure 3.14). The sitters included Slade, Wundt, and two of Zöllner's associates: Carl Ludwig, and Carl Thriesch. They allegedly witnessed Slade levitate a small pocket knife, and produce writings on slates in English, French, and German. At one point, Slade turned to Wundt, who was sitting next to him, and asserted that Wundt had the capacity to be "a medium of great power." Wundt apparently excused himself after about 20 minutes (Wundt, 1879). Although he had arranged the séance, Zöllner was not

present for these particular proceedings. He nevertheless wrote an account of the séance based on his subsequent conversations with Thriesch (Zöllner, 1880).

Wundt did not speak up about his experiences or his skepticism when Zöllner's conclusions about Slade's fourth-dimensional powers were first published in the British journal *The Quarterly Journal of Science* in April 1878. Wundt only publicly declared his doubts in response to an explicit challenge that was issued by another academic- Hermann Ulrici. Ulrici, a professor philosophy at Halle University, published an article discussing the implications Zöllner's experiments in the journal *Zeitschrift für Philosophie und philosophische Kritik*. Ulrici himself did not personally attend any of Slade's demonstrations, but he argued that, if Zöllner's reports were true, then they had profound implications for science. He noted that various prominent Leipzig academics had attended Slade's demonstrations, and he specifically called-out the various witnesses including Wundt, by name. Ulrici argued that anyone who had seen Slade in action and failed provide an alternative explanation than Zöllner's hypothesis must therefore be tacitly endorsing the idea that Slade was in contact with fourth-dimensional spirits of the dead. He wrote that the witnesses must either "demonstrate through their silence that they have nothing to support their doubts and that they simply choose not to believe the perfectly believable, or demonstrate how it could have been possible to deceive these men (and many other witnesses of unchallengeable credibility)." (Ulrici, 1878, p. 260, my translation).

In May of 1879, Wundt published an open letter, addressed to Ulrici, in which he questioned the spiritualist interpretation of the séances. His letter was translated and republished in America, in the magazine *Popular Science*. While Wundt did not offer specific explanations of phenomena, he proposed that they might be attributed

to ‘jugglery’ or sleight-of-hand. It was a mistake, he argued, to take Slade at his word that he did not have a magnet concealed somewhere. Wundt proposed that the physicists might not be the most qualified to detect deception. For example, when Slade deflected the compass needle with his hand, the scientists immediately began to discuss the implications in terms of ‘molecular forces.’ Non-scientists, Wundt said, would probably have been more concerned with checking Slade’s sleeves. It was suspicious, he went on, that the slate messages tended to be written in English or very poor German (Slade spoke almost no German). While Wundt made use of humour to undercut the spiritualist explanation of events, he arguably wrote very carefully to avoid directly confronting his more senior colleagues. This strategy made sense, considering his junior position at the University and the fact that the other scientists who participated in the investigations (Zöllner, Fechner, and Weber, in particular) were arguably his personal friends and mentors (Marshall & Wundt, 1980); Zöllner and Fechner had been instrumental in securing Wundt’s position at Leipzig (Kohls & Benedikter, 2010; Robinson, 2010).

Zöllner’s Open Letter to Wundt

While Wundt’s attempted diplomacy seemed to work for Fechner and Weber, Zöllner took the letter as a personal attack and a betrayal. When Zöllner published his 3rd volume of collected scientific papers- *Wissenschaftliche abhandlungen*- in October 1879, he prefaced it with a blistering 83-page open letter denouncing Wundt. He argued that Wundt’s dismissal of Slade’s feats as magic tricks was not in itself an alternative explanation because Wundt did not offer any explanation as to how the tricks might actually be accomplished. Zöllner even presented testimony from a magician, Samuel Bellachini, ‘Court Conjuror’ at Berlin, who had investigated Slade’s demonstrations and declared them to be absolutely impossible to replicate by

means of mechanical apparatus or sleight-of-hand (Bellachini quoted in Zöllner, 1879/1880). At other points, the content of the writing is one of the stronger arguments that Zöllner was mentally unstable during the time he was conducting experiments with Slade, although it is difficult to untangle when Zöllner is attempting to be deliberately satirical (Figure 3.15). Among the highlights of the diatribe are his suggestion that Wundt ought to be fined and imprisoned for slander. He also hypothesized that the magnetic forces that surrounded Slade might have “scrambled” Wundt’s brain (Zöllner, 1879, p. 76). Zöllner railed against what he saw as Wundt’s immoral materialism, and he noted that spiritualism had allowed him to overcome a deep personal depression when he discovered proof that his life might continue after death and was therefore not ultimately meaningless (Kohls & Benedikter, 2010).

Zöllner’s conclusion was particularly inflammatory. He noted that when Wundt had first met Slade, the American specifically remarked that Wundt himself appeared to possess latent mediumistic talents and had the potential to be a “medium of strong power”. Zöllner extrapolated that these gifts could have left Wundt vulnerable to malign influence from the spirit world. He proposed that Wundt’s objections to Slade might have been attributable to Wundt, himself, having been possessed and taken over by evil spirits. Zöllner ironically signed-off the letter with: “collegialischer Hochachtung” which translates roughly to ‘with deep collegial respect’ (Zöllner, 1879, p. 82)

3.2.5 The Aftermath of the Debate and Establishment of Wundt’s Lab

There is no record of Wundt ever responding to Zöllner’s accusations of magnetic brain scrambling or possession. Wundt was neither fined nor imprisoned, despite

Zöllner's suggestions, nor did he ever retract his statements. For the next, two-and-a-half years after Zöllner's open letter was published, both men continued to work and teach at the University of Leipzig. Zöllner's lectures remained popular courses at Leipzig, and in 1881 he published *Naturwissenschaft und Christliche Offenbarung*, a book in which he explained the miracles of the bible in terms of fourth-dimensional physics. In early 1882, Wundt unsuccessfully petitioned the university for an annual budget for his nascent laboratory (Bringmann, Bringmann, & Unger, 1980). Later that year, on April 25, 1882 Zöllner died suddenly of a stroke at the age of 47 (Marshall & Wendt, 1980). Following Zöllner's death, the University of Leipzig assigned Wundt to lead the task of selecting Zöllner's successor for the physics chair. Rather than recruiting a new chair, Wundt was able to reallocate Zöllner's former budget towards developing his own nascent psychology laboratory. Following the laboratory's successful expansions, the University officially recognized Wundt's *Institute of Experimental Psychology* in 1883, and assigned it a regular annual budget (Bringmann, Bringmann & Ungerer, 1980) – making it the world's first ever formally recognized experimental psychology laboratory.¹²

Aside from Zöllner's *Scientific Papers* and Wundt's letter, one other source of information on Slade's séances in Leipzig comes from an investigative commission based out of the University of Pennsylvania. The Seybert Commission was formed at the behest of Henry Seybert, a wealthy Pennsylvanian spiritualist and philanthropist who donated money to establish a professorship of moral philosophy and fund a

¹² This date/location (1883/Leipzig) for the 'First Experimental Psychology Laboratory' is somewhat debatable (e.g. Cattell, 1928), but 1883 *does* mark the lab where (a) experimental psychology research was conducted that was (b) officially sanctioned by a university. William James had established a teaching laboratory at Harvard in 1875, but the lab was exclusively for teaching and demonstration purposes *not* experimental research. And Wundt was conducting experiments as early as 1879, but on an ad hoc basis that was not officially sanctioned by the University of Leipzig.

scientific investigation of the reality of spiritualistic claims. The Commission was active from 1883 to 1887 and investigated a variety of phenomena including spirit rappings, slate writings (Pepper et al., 1887). Henry Slade and the Zöllner experiments were central to their slate writing investigation. In 1885, Slade himself travelled to Pennsylvania at the commission's invitation to demonstrate his slate writing skills. The commission was highly unimpressed with Slade's feats – concluding that his slate writing was “performed in a manner so closely resembling fraud as to be indistinguishable from it” (p. 21). They believed that they saw Slade attempting to switch pre-written slates for ostensibly blank ones, and even saw him use his foot to try to create the illusion of levitating furniture around him. Notably, they also consulted a professional stage magician, Harry Kellar, who also demonstrated his slate writing ‘powers’ to the committee. Kellar's phenomena were judged by the committee to be much more impressive and convincing than Slade's and, following his performance, Kellar demonstrated the exact natural methods behind his tricks (for example see Figure 3.19).

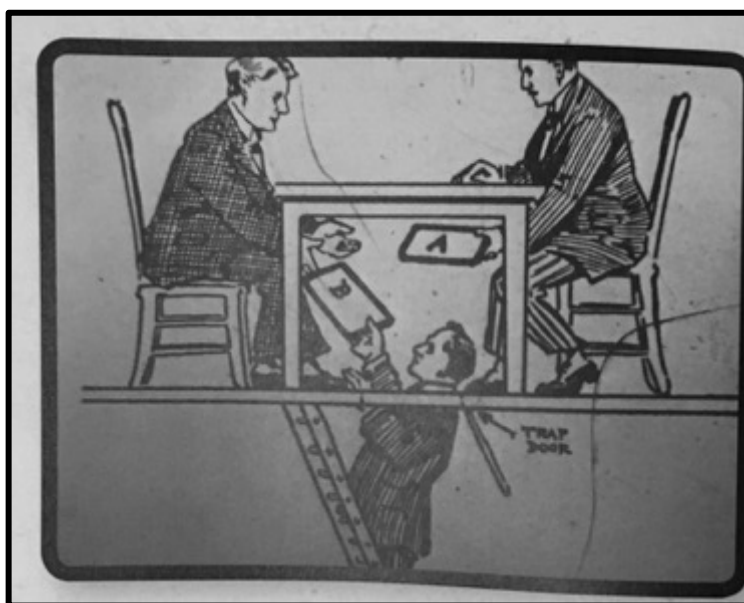


Figure 3.19. One of the slate writing methods that Kellar demonstrated to the Seybert Commission (slide from Houdini's Spiritualist Lecture in Moses, 2009)

Additionally, a representative of the commission, Professor George S. Fullerton, travelled to Leipzig to interview the surviving witnesses of Zöllner's experiments, including Wundt, Weber, and Fechner. The commission drew highly skeptical conclusions from the interviews. Fullerton reported that Fechner was in fact mostly blind and had based most of his conclusions on Weber, who was arguably somewhat senile; Zöllner himself was allegedly of 'unsound mind,' and apparently had a family history of mental illness. The report questioned the scientific rigor of the sittings, noting that Slade was always in control of the 'experimental' conditions, and that Zöllner trusted him to be honest. The commission published its report, including its investigation of the Zöllner experiments, in 1887. While the report was published as a 'Preliminary Investigation' no further investigations were ever published; however, to this day, the University of Pennsylvania still maintains a Seybert Chair as part of its Philosophy Department (although it no longer focuses on spiritual investigations).

As for Slade, he continued to travel and practice. His tour continued to Russia (Doyle, 1926) and Australia (Curtis, 1902), and he even returned to England briefly, practicing under the false name ‘Mr. Wilson’ (Davey, 1888), before eventually settling again in America. He would never again achieve the acclaim or notoriety that he had found in London or Leipzig. Towards the end of his life, he apparently descended into alcoholism, and died in a sanatorium in Michigan in 1905 (Figure 3.20). Four days after his death, the *New York Times* ran a story noting that he had not returned as a spirit (“Didn’t See Slade’s Spirit,” 1905).



Figure 3.20. Henry Slade’s grave at Riverside Cemetery in Albion, MI (photo by Passic, 2003)

3.3 Early Psychological Approaches to the Science of Magic (1888- 1900): Deception, Legerdemain, and Conjuring

As psychology was emerging as a formal science, a group of early researchers: Joseph Jastrow, Max Dessoir, Alfred Binet, and Norman Triplett all published articles on the science of deception with particular attention to performance and perception of magic tricks. In the context of the time, each of these papers can be considered, at least partly, as a reaction to the events in Leipzig and the Wundt-Zöllner debate. Psychologists were struggling to establish themselves as a legitimate branch of science. This strive towards legitimacy applied to both the experimental psychologists like Wundt and James but also to psychical researchers who were looking to investigate spiritualistic claims like thought reading or survival after death. Throughout the early part of the 20th century, the terms psychologist, psychicist, and psychical researcher were largely interchangeable in both public and academic discourse (e.g. Ruckmich, 1918). Some early psychologists appealed to illusions as ways of scientifically approaching reports of paranormal experiences, rather than re-writing established aspects of natural science to accommodate reports of paranormal phenomena, they instead sought to explain how people could come to *experience* the phenomena (even if the phenomena themselves were not necessarily real).

Records of psychologists interested in applying psychological science to the study of magic can be traced back to 1888, when Joseph Jastrow (1863- 1944, Figure 3.21) wrote a short article on deception and illusion, with particular focus on conjuring tricks. Joseph Jastrow was a Professor of Experimental Psychology at the University of Wisconsin from 1888 to 1927 and might be labelled the world's first 'Popular Psychologist.' His focus was on the public perception of psychology- using

the scientific method to educate the lay-public. He tirelessly promoted the science of psychology through various media including formal papers, newspaper and magazine articles, public lectures, self-help books, and even radio lectures (Blumenthal, 1991; Pettit, 2007). He also wrote on the topic of spiritualist frauds, Ouija boards, optical illusions (he was also responsible for introducing the DuckRabbit figure to psychology- Jastrow, 1899), belief, and dreams (Jastrow, 1900). He collaborated with Hugo Münsterberg and G. Stanley Hall to present a psychology exhibit at the World's Columbian Exposition in Chicago in 1893 (Benjamin, 2004). And, towards the end of his life, he attempted to publish psychological analysis of Hitler and Nazi Germany. His interest in magic seems to be related to an interest in spiritualism, and his skepticism can arguably be traced back to the Wundt-Zöllner debates in Leipzig, given that he studied under G. Stanley Hall, who himself had studied directly under Wundt in Germany (Thorndike, 1925). In his 1888 paper, his assertions regarding sensations and illusions arguably anticipate later work on unconscious inference and schema theory (Hyman, 1989). He wrote that he was especially concerned with “the formation of false beliefs leading to erroneous action.” He notes that inducing false perceptions or illusions is merely the first step towards deception: these illusions must then be converted to false beliefs by ‘changing the mental attitude of the spectator. To illustrate his point, he invited his readers to consider the contrast between the performances of a magician and a fraudulent spiritual medium. In the case of the magician, the spectators know that what they see is a trick or an illusion, while the medium will endeavour to convince the spectators that the illusions that he creates are genuinely real.



Figure 3.21. A portrait of Joseph Jastrow (public domain image from Wikimedia Commons)

In a subsequent paper, Jastrow (1896) conducted a series of psychophysical tests on a pair of famous stage magicians: Alexander Hermann and Harry Kellar (Figure 3.22). Jastrow reported a series of tests that he had conducted on a pair of famous stage magicians: Harry Kellar and Alexander Hermann aka ‘Herman the Great.’ Having hypothesized that the expert performers might possess ‘exceptional powers,’ either inherently or as a result of their extensive training, Jastrow examined the magicians’ tactile and motor function, visual perception, and memory. To Jastrow’s apparent surprise, none of the tests varied from normal ranges- although he noted that the magicians had slightly quicker reaction times in response to visual, tactile and, in Kellar’s case, auditory, stimuli. Jastrow concluded that “special skill in one very specialized form of training may be only slightly influential upon other forms of capacity” (p. 689). He closed by cautioning that the tests that he had used were more suited to being averaged across large groups rather than small samples.



Figure 3.22. Theatrical posters from Alexander Hermann and Harry Kellar, the two magicians who were tested by Joseph Jastrow (public domain images via Wikimedia Commons)

Around the same time, another psychologist, Max Dessoir (1867-1947, Figure 3.23) published a five-part series of articles on ‘legerdemain’ in *The Open Court* (1893). Highlights of Dessoir’s articles include discussions of social and temporal misdirection. He writes that the ‘intense expectations’ deliberately generated by magicians can induce illusory experiences similar to hallucinations. Interestingly he is the first psychologist to make reference to the vanishing ball illusion (Dessoir, 1893e) that would later be adapted by 21st century researchers (e.g., Kuhn et al., 2005). At the time that his magic articles were written, Dessoir was a Lecturer in Philosophy, although he later went on to be the chair of Psychology and Psychiatry at Berlin University. Dessoir was heavily involved in the contemporary debates about using science to investigate apparently supernatural phenomena, and he is credited with popularizing the phrase ‘parapsychology’ (Sommer, 2013). Dessoir also performed as a semi-professional magician under the stage name Edmund W. Rells

(Whaley, 2006).



Figure 3.23. Portrait of Max Dessoir (Public Domain Image via Wikimedia Commons)

Alfred Binet, another prominent early psychologist, also published a short paper on magic. Better known as one of the developers of the first intelligence test (Binet & Simon, 1916), Binet published an article titled *The Psychology of Prestidigitation* in 1894. While Binet did not conduct formal experiments, he did report the first ever filming of a magic trick performance. Collaborating with cinematographer Georges Demeny, Binet arranged for the ‘chronophotography’ of magicians Arnould and Raynaly (Thomas et al., 2016). Their performances were recorded with what, at the time, was a revolutionary 12 photographs per second (see Figure 3.24). Examining these images led Binet to conclude that photography effectively destroyed the magic effects; he concluded that photos stripped away all elements necessary to maintain the illusion. Ironically, another magician who visited Binet’s laboratory, George Melies, would go on to pioneer the use of special effects in cinema (Lamont, 2010). Melies’ movies, such as *A Trip to the Moon*, were largely

based around the successful adaptation of stage illusions, to create effects like having actors inexplicably vanish in puffs of smoke.



Figure 3.24. A still from a surviving film of Raynaly performing a vanish of a ball- originally recorded in Binet's lab in 1893, rediscovered by Richard Wiseman (2005).

Another student of G. Stanley Hall, Norman Triplett (Figure 3.25), produced a doctoral thesis on conjuring deceptions, which was published in Hall's *American Journal of Psychology*. Triplett (1900) reviewed and categorized hundreds of magic trick methods. He also discussed the theories on the origin of conjuring, starting with ideas about an evolutionary basis of a 'deception instinct,' and considering the sociological implications of early religious practices. Triplett also conducted informal experiments relating to children's perceptions of magic, specifically on their reactions to a vanishing tennis ball effect. He would visit classrooms and perform seated behind a teacher's desk. He would begin by tossing a tennis ball into the air, catching it each time by dropping his hand below the table. He would make two real tosses, and then rather than throwing the ball a third time, he would secretly drop it into his lap and pantomime the action of again throwing it into the air. He then asked the children to write down what they had seen. Of the 165 respondents, 78 reported seeing the ball travel upwards and vanish into thin air on the third toss. Triplett notes that he achieved similar results using with adults, and also when using different

objects, including an apple and a silver dollar. These vanishing tricks would later be replicated by 21st century psychologists (Kuhn & Tatler, 2006).

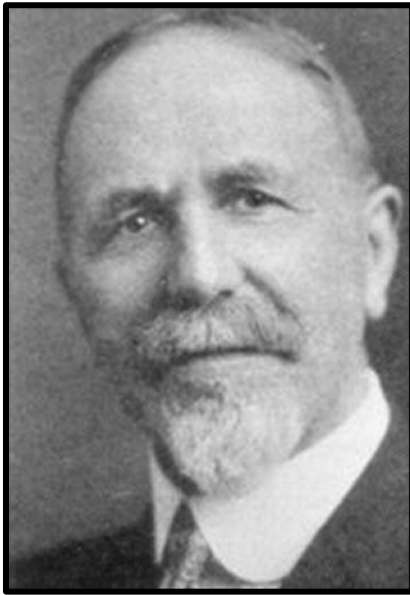


Figure 3.25. Portrait of Norman Triplett (Public Domain image via Wikimedia Commons)

3.4. A Contemporary Science of Magic

Historically, this burst of interest in psychology of magic was relatively short-lived and largely vanished along with deception literature in 1900. The reason for this apparent lack of interest may be attributable to rise of behaviorism and rejection of ‘mentalistic’ concepts (Hyman, 1989; Rensink quoted in Romm, 2015). For the next century, scientific articles on magic generally took the form of editorials and opinion pieces calling for further investigation. While there were some notable efforts to integrate magic literature with scientific literature (Lamont & Wiseman, 1999), actual experiments on adult perceptions of performance magic were generally not conducted. After Hodgson and Davey’s writings, along with Jastrow’s report of Hermann and Kellar, and Triplett’s report of the vanishing ball illusion (each of which were published in the late 1800’s), there were a total of only 9 empirical investigations of magic (involving adult participants) published between 1901 and 2001. (See Appendix A): Six articles that examined how witnessing magic tricks might relate to spectators’ credulity towards ostensibly supernatural phenomena

(Besterman, 1932; Marcuse & Bitterman, 1944; Jones & Russell, 1980; Benassi & Singer, 1980; Smith, 1993; Wiseman & Morris, 1995); two articles on magic and judgments of causality (Subbotsky 1997; 2001); and one experiment to test the claims of a magician about how people can be influenced to guess particular numbers in the context of a ‘mind reading’ magic trick (Trinkhaus, 1980). A number of additional researchers did express their interest in the topic (e.g., Kelly, 1943; Gregory, 1980; Kelly, 1977; Nardi, 1984) but their writings did not lead directly to any actual experimental research.

This relative lack of empirical research has shifted dramatically in the past 15 years. Today, psychologists are increasingly aware that the illusions involved in performance magic can be used not just as a rhetorical device to explain away reports of paranormal experiences and pseudoscientific concepts, but as tools for driving new research into human cognition (e.g. Thomas, Didierjean, Maquestiaux, Gyga, & Pascal, 2015). Not only have the number of empirical papers published about magic and magicians more than quadrupled in the past 15 years, but there have been at least three international academic conferences, one organized by the Association for the Scientific Study of Consciousness in 2007, and two by the recently developed Science of Magic Association in 2016 and 2017 (with another scheduled for 2018). Magic tricks are being used in university classrooms to illustrate concepts about perception and cognition and to promote critical thinking.

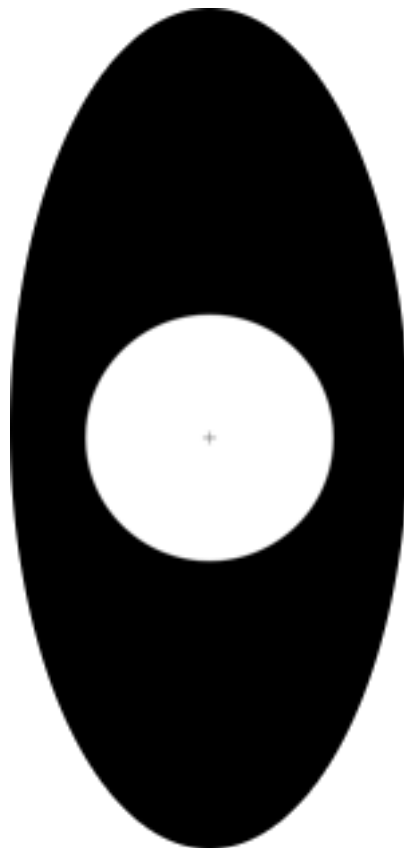
Chapter 5 of this thesis will review contemporary science of magic research as it relates to attention and perception, before presenting a novel empirical contribution to the literature. Overall, the work presented in this thesis embodies the idea of approaching the study of magic as a soft sub-discipline of psychology. The past two chapters have demonstrated how the examination of magic history can offer

new perspectives on the history of science and psychology, particularly in the areas of attention and perception. My subsequent empirical chapters (especially chapters 5 and 6), will show how magic trick methods can be adapted to develop novel research paradigms to investigate human perception and memory. Throughout the years I have been working this project, I believe my interest in magic has helped enhance my work as a scientist while my scientific research has also helped develop as an artist, in terms of my work as a magician.

Chapter 4

Now You See It

**An Investigation of the
Role of Semantic Attentional Set
in Inattentional Blindness**



Inattentional blindness refers to the failure to detect and report an unexpected object or event, which is fully visible and in plain sight, when attention is engaged by another task. We conducted a series of experiments to investigate semantic attentional set –how meaning can influence whether or not an unexpected stimulus is detected and reported, depending on the task that the observer is engaged in. Participants who were engaged in a picture-naming task tended to be attentionally blind to unexpected words that were presented to them at fixation for 1200 milliseconds. In conditions where the unexpected word was semantically congruent with the picture-naming task (e.g. participants looking for fruit pictures were presented with the word GRAPES), inattentional blindness was almost entirely eliminated. However, rates of inattentional blindness were only modulated when the unexpected word was taxonomically-related to the pictures that the participants were looking for. Other types of semantic congruencies, including thematic and functional relationships failed to consistently modulate inattentional blindness rates. These results suggest that, while attentional set can be tuned for meaning, when attention is tuned semantically, it is also tuned narrowly. Semantic congruency, in and of itself, is not necessarily sufficient to modulate inattentional blindness.

4.1 Introduction

Most people believe that they simply need to look in order to see (e.g. Simons & Chabris, 2011). Yet we can be blind to objects that are in plain sight if we are not actively attending to them. The term inattention blindness (IB) was coined by Mack and Rock (1998), to describe this failure to notice an unexpected object or event, which is fully visible and in plain sight, because attention is otherwise engaged. Multiple studies have dramatically demonstrated this phenomenon can apply to various stimuli including simple geometric shapes, to airplanes, motorcycles, unicycling clowns, fire extinguishers, simulated assaults, and even gorillas (Mack & Rock, 1998; Haines, 1991; Most & Astur, 2007; Hyman et al., 2010; Castel et al., 2012; Chabris et al., 2011; Simons & Chabris, 1999).

The fact that people can fail to have conscious perceptions of unexpected stimuli raises the question as to what circumstances are necessary for a stimulus to enter awareness.

Such research suggests that our day-to-day visual awareness may be highly dependent on attention and on expectation. Without specifically focusing our attention, we can easily look directly at something but fail to see it. This concept can have everyday consequences, manifesting in phenomena like ‘look-but-fail-to-see’ traffic accidents (Hills, 1980), wherein a driver, whose attention is otherwise engaged, can drive directly into something that they are looking at.

This presents a paradox. If attention is necessary for visual awareness, and unexpected objects do not necessarily capture attention, how can attention be tuned so that we can see things that we are not actively looking for?

This question has been addressed by manipulations of the primary task and critical stimulus. IB paradigms involve two fundamental elements: a primary task and an unexpected stimulus. The primary task refers to an activity the participant is instructed to engage in. The unexpected stimulus refers to the unexpected object or event that is presented to the observer, who is actively engaged in the primary task. Rates of inattention blindness refer to the likelihood that a participant will fail to notice the unexpected critical stimulus. The first experiments to be categorized as inattention blindness studies involved static serial displays (e.g., Mack & Rock, 1999; Figure 4.1). In these studies, the critical stimulus was presented along-side the primary task stimuli. Subsequently, experiments that would have previously been classified as ‘selective looking’ paradigms (see Neisser, 1979 for review) have also been categorized as IB experiments; these experiments typically involve dynamic stimuli. The stimuli for ‘selective looking’-style IB experiments can range in complexity from animated geometric shapes (e.g. Most, School, Clifford, & Simons, 2005) to live-action video recordings (e.g., Simons & Chabris, 1999; Simons, 2011; Figure 4.2), or even ‘live’ staged events (e.g., Hyman et al., 2009; Chabris et al. 2011). In addition to the primary task and the critical stimuli, these experiments also include distractor stimuli that the observer must ignore while engaging in the primary task.

Past research has demonstrated that the primary task can influence IB based on attentional load, i.e. more difficult primary tasks generally result in higher rates of IB (Cartwright-Finch & Lavie, 2006). Additionally, certain critical stimuli, like participants’ written names and schematic happy faces, have been shown to be noticed under conditions where other kinds of stimuli would be subject to inattention blindness (e.g. Mack, Papas, Silverman & Gay, 2002; Lin & Yeh, 2014).

Similar effects have been demonstrated with images of body parts (Downing et al., 2004) and animate objects (Cavillo & Jackson, 2014).

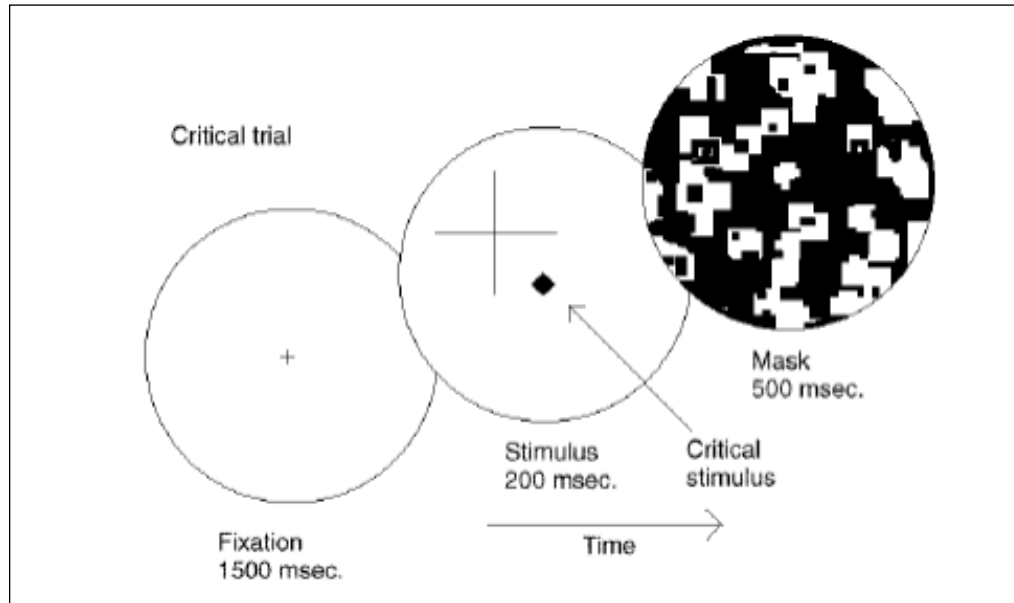


Figure 4.1. Mack and Rock's (1998, p. 7) cross-arm discrimination task. Participants' task was to determine which arm of the cross was longer. The critical stimulus was an unexpected diamond shape appeared at fixation.



Figure 4.2. Simon's and Chabris' (1999) video experiment: the primary task involved counting the number of basketball passes that were made by either white-shirted players or black-shirted players. The critical stimulus was a woman dressed in a gorilla costume that strolled through the frame (image from Simons, 2011)

The relationship between primary task and critical stimulus can also influence IB. The more perceptually similar a critical stimulus is to primary task items, the less likely participants are to be inattentionally blind. This pattern of results has been related to attentional set theory (e.g. Folk, Remington & Johnston, 1992; Lamy, Leber, & Egeth, 2004), which proposes that the perceptual thresholds of objects vary according to the task-related goals of the observer. In other words, top-down factors related to observers' goals will directly influence the likelihood that certain elements of external stimuli will be detected. The impact of attentional set and perceptual congruency on inattentional blindness has been well documented in terms of low-level perceptual features like colour (Simons & Chabris, 1999), shape (Most et al., 2005) and luminance (Most et al., 2001). These findings support the idea that attentional set can be 'tuned' according to task demands.

Recently, the concept of attentional set has been extended beyond perceptual features to encompass semantic relationships. This idea, that IB can be modulated by ascribing contextual meaning to the critical stimulus is still relatively unexplored. Most (2011; Figure 4.3) demonstrated that IB rates can be influenced by semantic category using a dynamic IB paradigm. The phenomenon that IB rates can depend on *semantic* features of the critical stimulus that are shared with task-relevant stimuli, has been referred to as the "semantic-congruency effect" (Koivisto & Revonsuo, 2007).

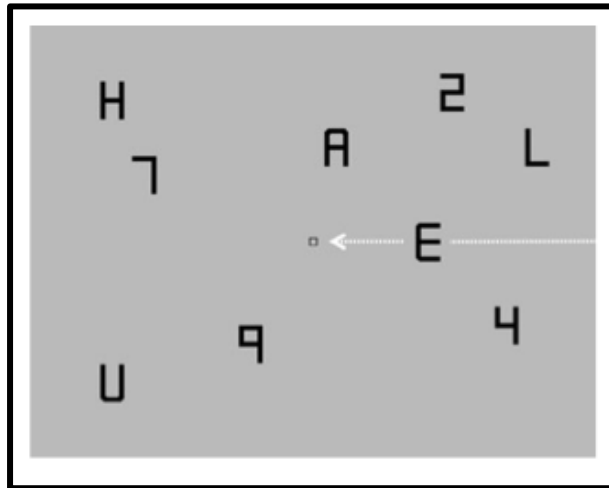


Figure 4.3. Most's (2011) dynamic IB experiment. Participants' task was to attend either numbers or letters and to count the times the attended items "bounced" off the edge of the screen on the computer display. The critical stimulus took the form of a block letter E or a number 3, which moved horizontally across the centre of the display from right to left. Because the critical stimuli were drawn to be perceptually similar, participants were forced to discriminate based on semantic category instead of lower-level visual features. Nevertheless, participants exhibited significantly lower IB rates for the critical stimulus when it corresponded with the attended category.

The present study is modelled after a static IB paradigm (Koivisto & Revonsuo, 2007) where participants' primary task was to identify line drawings of animals or furniture. The drawings were always presented in a four-item array around a fixation cross. In the original paradigm, the critical stimulus was a written word, appearing at fixation, and it was related either to animals or furniture (see Figure 4.4). The critical stimuli and primary-task items were presented in different mediums (written words and line drawings), and thus they did not share perceptual features. Nevertheless, participants were significantly less likely to be inattentionally blind to an unexpected word when it was related to the task they were engaged in; this semantic congruency effect is at least partially independent of perceptual load (see Koivisto & Revonsuo, 2009).

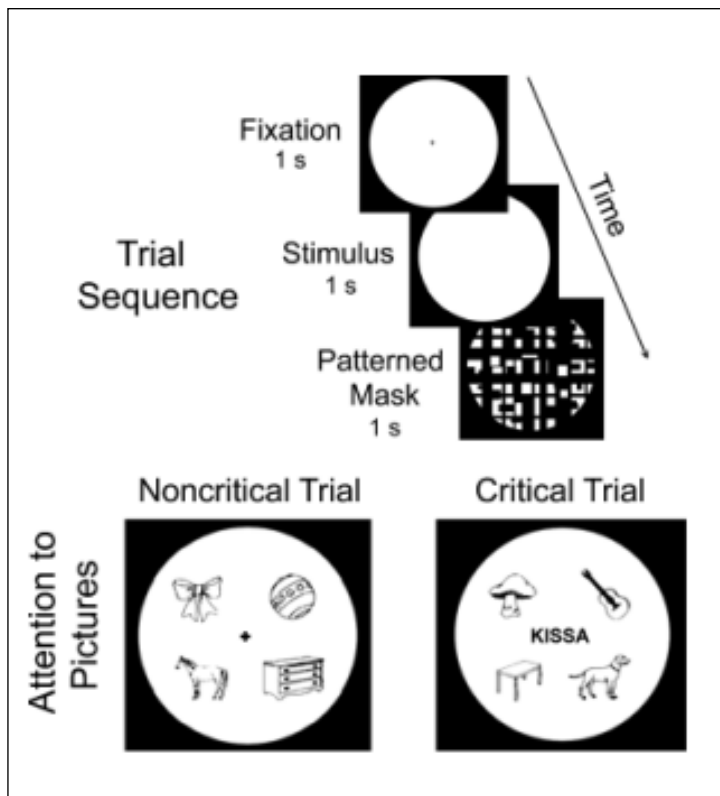


Figure 4.4. Koivisto and Revonsuo's (2007) picture-naming task. Participants' task was to name the pictures of a particular category. On the critical trial an unexpected word appeared in the centre of the pictures. In the example above, 10% of participants were inattentionally blind to the word CAT when instructed to attend pictures of animals while 60% of participants were inattentionally blind to the word CAT when instructed to attend to pictures of furniture.

4.1.1 The Current Experiment

The current experiment seeks to clarify the mechanisms of the semantic-congruency effect by considering the relationship between the primary task and critical stimuli with regards to the concept of semantic categorisation. Categories can be based on shared attributes of the concepts and on the manner in which one might interact with the concepts (Rosch & Mervis, 1975; Rosch, 1976). The proposal that categorization relates to function is particularly relevant in light of converging results from word priming studies (Lucas, 2000; Hutchinson, 2003), change blindness experiments (e.g. Triesch et al, 2003; Symes et al., 2008), as well as more general neuropsychological evidence (Moss & Tyler, 1995; Humphreys & Riddoch, 2001) that associations between objects and actions can facilitate perception. Using a paradigm derived from Koivisto and Revonsuo (2007), we examined IB rates involving two new types of relationships: non-exemplar semantic associations and functional associations. In light of this literature, as well as unpublished research that had been conducted in our lab (Mansell, 2011), I hypothesized that non-exemplar semantic relationships would be insufficient to modulate IB, such that rates of IB would be unchanged whether the attended pictures were congruent or incongruent with the critical word. Additionally, I hypothesized that categorical attentional set would encompass functionally associated critical stimuli. Thus, IB rates would be lower for words that were functionally associated with the attended category.

4.2. Methods

4.2.1. Participants

259 neurologically healthy native-English speaking participants with normal to corrected-to-normal vision were recruited from the University of Oxford. They

were tested following a protocol approved by the University of Oxford Research Ethics Committee. Each participant was tested individually and given £5 as compensation for their time.

Six participants were removed from the final IB analysis because they participated only in the pilot conditions. A further 13 were removed, either because they failed to follow instructions ($n = 9$), or they had previously participated in a similar IB paradigm ($n = 4$). The remaining 240 participants (138 females, mean age 23.3 years) were distributed randomly across the 13 experimental conditions.

4.2.3. Apparatus

The experiment was run on a CRT monitor (32.2 cm x 24.1 cm), operating at a refresh rate of 60 Hz and a spatial resolution of 1024 x 768 pixels. Monitor viewing distance was fixed at 50 cm, using a forehead and chin rest. The experiment was programmed and presented in E-basic (E- Prime, v2, Psychology Software Tool Inc., USA). The stimulus displays were matched in terms of visual angle to the original display size used by Koivisto and Revonsuo (2007).

4.3.4. Stimuli and Procedure

Stimuli included nine pictures of vehicles and ten pictures of fruits selected from Snodgrass and Vanderwart's (1980) set of normalised line drawings; two additional vehicle pictures (a wagon and a tractor) were added to the stimulus set after being modified to match the visual complexity of the Snodgrass images. Within the experimental trials, vehicle and fruit pictures were chosen to approximately match in terms of visual complexity, typicality, and familiarity (See Appendix D for complete instruction materials and Appendix E for complete stimulus materials).

The experimenter read aloud one of two sets of standardised instructions. The instructions differed depending on whether the participant was told to:

“Report the Vehicles and Ignore the Fruits” or

“Report the Fruits and Ignore the Vehicles”.

To familiarise them with the trial procedure, participants completed a paper version of the task, based-on the standard four-picture array. The paper version consisted of a blank page (intended to represent the blank computer screen), a page depicting a fixation slide, a page depicting a stimulus slide that contained an array of two vehicles and two fruits (raspberry, lemon, tank, sled), and a review page depicting a fixation screen, a stimulus slide, and a blank screen. None of the pictures in the paper version appeared as stimuli in the computerised experimental trials.

Each participant completed a total of seven trials. Every trial began with a 1-second presentation of a fixation cross that was centred in a round white viewing area (12.2° visual angle), superimposed on a black background. Four pictures of vehicles and fruits, (each $2.7^\circ \times 2.7^\circ$) appeared at four locations flanking the central fixation cross. The far corner of each picture was 3.7° from the cross. The pictures remained on the screen for 1200 ms, after which, a blank screen prompted participants to report aloud the names of the pictures that fit the category that they had been instructed to attend. Having reported the pictures, participants were then prompted by the experimenter to press the spacebar to initiate the next trial. Trials 1-4 contained four pictures arrayed around the fixation cross; these trials are referred to as *non-critical trials*. Trials 5-7 also contained a four-picture array, but instead of presenting a cross in the centre of the spotlight while the pictures were being displayed, these trials contained an unexpected written word in the center of the

screen. Trial 5, the *critical trial*, was of primary research interest because it was the first trial where an unexpected word (referred to as the critical stimulus) appeared. The words were always presented in Arial font, at a height of 0.7 °. The critical stimulus was one of six words (TRUCK, GRAPES, TRAFFIC, RIDE, DRIVE, STEER) that depended on the condition (see *Figure 4.5* for an example of a non-critical and critical trial and *Figure 4.6* for an example of a full trial pattern).

Two of the first four trials contained one vehicle and three fruit pictures, and the other two trials contained one fruit and three vehicle pictures. To control for the possibility of participant's expectations being affected by the order or number of category items being presented in the non-critical trials, these trials were presented in two different orders that were randomised across participants. Trial Pattern 1 began with a one vehicle and three fruits trial, followed by a three vehicles and one fruit trial, then a three vehicles and one fruit trial, and then a one vehicle and three fruits trial. Trial Pattern 2 had the reverse order, and began with a three vehicles and one fruit trial (see Tables 4.1 and 4.2 for a full description of the two trial patterns). The four pictures presented on Trial 5, the critical trial, were always two vehicles and two fruits, and exactly the same four pictures were shown again on Trials 6 and 7.

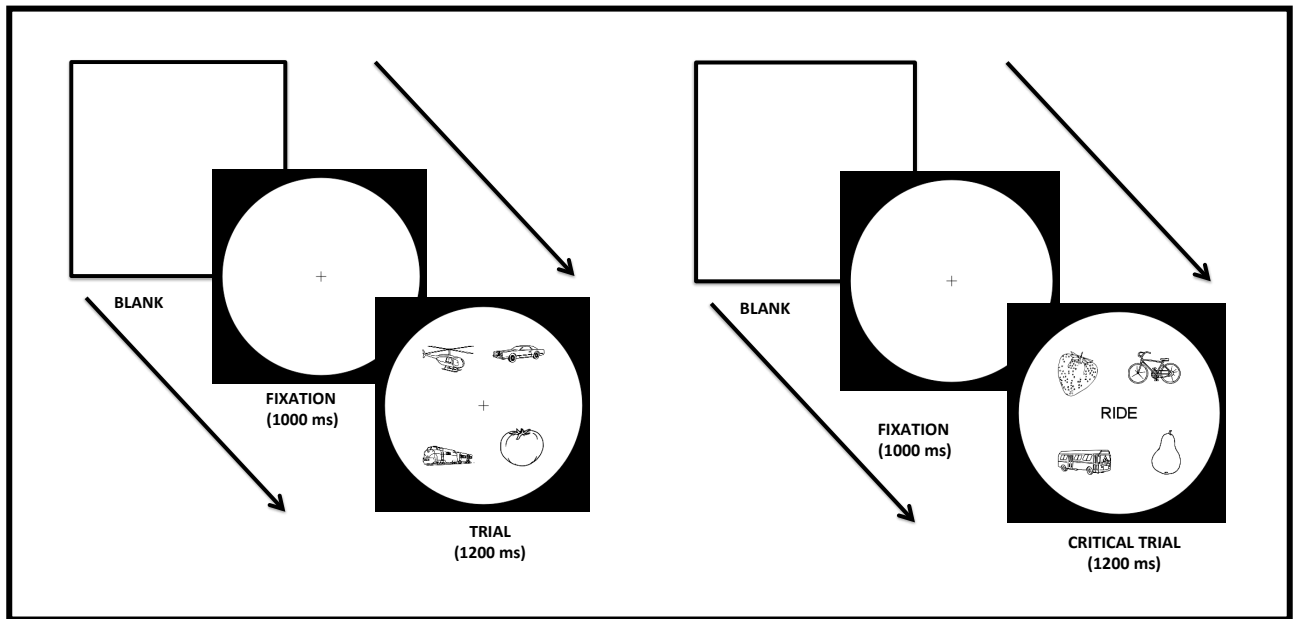


Figure 4.5. Example presentations of a non-critical trial (left) and a critical trial (right). The main difference between the trials was that a word appeared at fixation on the critical trial.

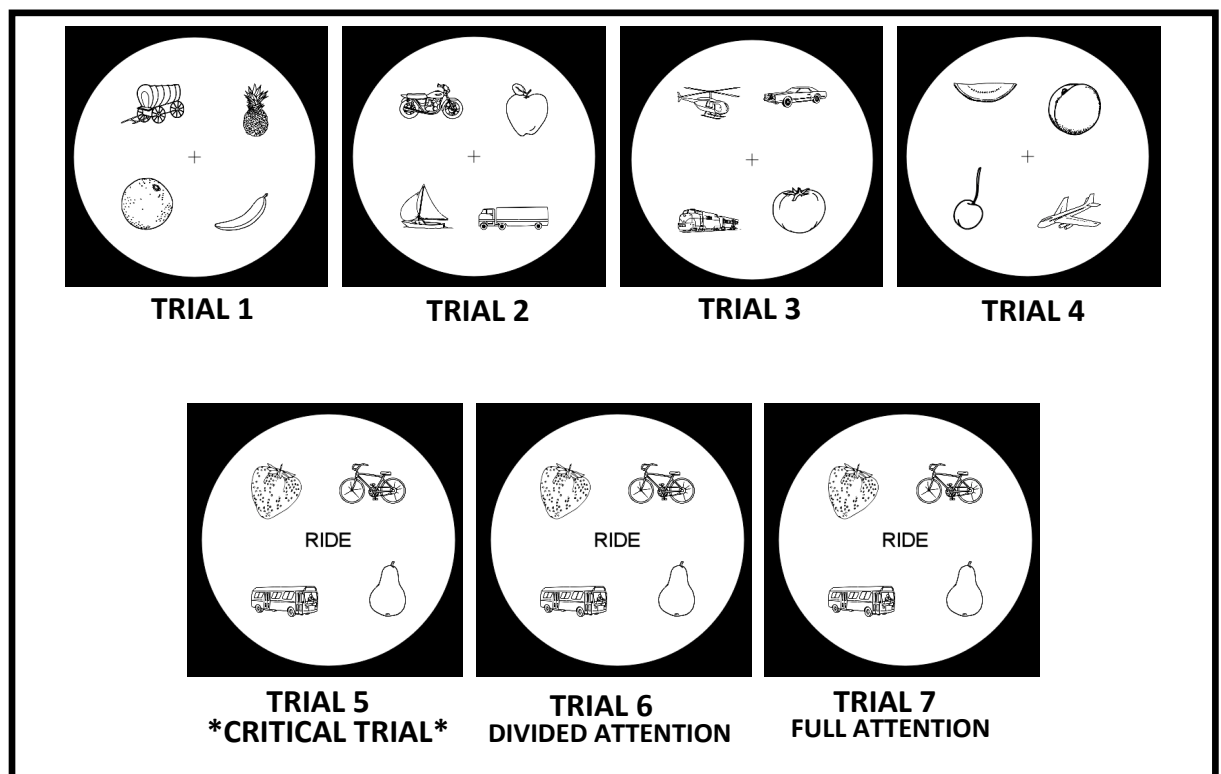


Figure 4.6. Example of Trials 1-7, Half of the participants were presented with this trial pattern (see Tables 4.1 and 4.2 for the order of pictures presented in all the possible trial patterns). Participants viewed four non-critical trials (top row) before the critical trial. The critical trial was followed by two identical trials (divided-attention and full-attention). The full attention trial was accompanied by different instructions for participants.

Immediately after the participant reported the attended pictures on the critical trial, the experimenter asked:

“There were four pictures on the last trial. Did you see anything other than the four pictures?”

If the participant responded “Yes,” s/he was asked to describe exactly what s/he had seen and where what was seen had been located. Participants who were able to report the presence of word and to say either exactly what the word said or where on the screen the word had appeared were classified as to having noticed the critical stimulus. Thus, participants who reported the critical stimulus were referred to as noticers, and those who failed to report it, non-noticers; that is, they were considered to have been inattentionally blind to the critical stimulus. Following these questions about the critical stimulus, all participants (both noticers and non-noticers) were asked to report the pictures from the category they had been instructed to ignore.

Trial 6 is referred to as the *divided-attention trial*, because, on the previous trial participants had been asked: *“Did you see anything other than four pictures”* and had also been asked to report pictures from the ignored category. Otherwise, this trial was identical in all ways to the critical trial. Trial 7 was referred to as the *full-attention trial*. Participants viewed exactly the same pictures and the written word that had appeared on the critical and divided-attention trials, but, for this final trial, participants received new instructions prior to the presentation:

“Ok, this is your final trial, and your instructions are slightly different. As before, start with your eyes fixated on the fixation point, but this time you do NOT need to report any of the pictures. Simply watch the display. Ready?”

Trial 7 was referred to as the *full-attention trial* because it was designed to verify that the participant could detect the critical stimulus when attention was not engaged in the primary picture-naming task. The questions following Trial 7 (full-attention trial) were identical to those following Trial 5 (critical trial) and Trial 6 (divided-attention trial) in regard to detection, identification and location of the critical stimulus. However, unlike on Trial 5 and 6, participants were not asked to report pictures from either the attended or ignored category, but were simply asked if they had seen anything other than the four pictures.

Table 4.1.

*Complete List of Picture Stimuli in Conditions 1-10 and 12**Listed in Order of Presentation for Each of Two Possible Trial Patterns*

	Pattern 1		Pattern 2	
	<i>Vehicles</i>	<i>Fruits</i>	<i>Vehicles</i>	<i>Fruits</i>
Trial 1 <i>(Pattern 1: 1 Vehicle, 3 Fruits Pattern 2: 3 Vehicles, 1 Fruit)</i>	Wagon	Banana Pineapple Orange	Motorcycle Boat Truck/Tractor*	Apple
Trial 2 <i>(Pattern 1: 3 Vehicles, 1 Fruit Pattern 2: 1 Vehicle, 3 Fruits)</i>	Motorcycle Boat Truck/Tractor*	Apple	Wagon	Banana Pineapple Orange
Trial 3 <i>(Pattern 1: 3 Vehicles, 1 Fruit Pattern 2: 1 Vehicle, 3 Fruits)</i>	Train Car Helicopter	Tomato	Airplane	Cherry Watermelon Peach
Trial 4 <i>(Pattern 1: 1 Vehicle, 3 Fruits Pattern 2: 3 Vehicles, 1 Fruits)</i>	Airplane	Cherry Watermelon Peach	Train Car Helicopter	Tomato
Trials 5, 6, and 7 (Critical Trial, Divided-Attention Trial, and Full-Attention) <i>(2 Vehicles, 2 Fruits)</i>	Bicycle Bus	Pear Strawberry	Bicycle Bus	Pear Strawberry

*When TRUCK was the critical stimulus word. The truck picture was replaced with a picture of a tractor to avoid possible priming effects resulting from the participants seeing the picture and naming it before it was presented on the critical trial. We did not want participants to say the word 'truck' in response to the picture, prior to being shown the written critical stimulus word TRUCK.

Table 4.2.

*Complete List of Picture Stimuli in Condition 11
Listed in Order of Presentation for Each of Two Possible Trial Patterns*

	Pattern 1		Pattern 2	
	<i>Vehicles</i>	<i>Fruits</i>	<i>Vehicles</i>	<i>Fruits</i>
Trial 1 <i>(Pattern 1: 1 Vehicle, 3 Fruits Pattern 2: 3 Vehicles, 1 Fruit)</i>	Wagon	Banana Pineapple Orange	Motorcycle Boat Bus	Apple
Trial 2 <i>(Pattern 1: 3 Vehicles, 1 Fruit Pattern 2: 1 Vehicle, 3 Fruits)</i>	Motorcycle Boat Bus	Apple	Wagon	Banana Pineapple Orange
Trial 3 <i>(Pattern 1: 3 Vehicles, 1 Fruit Pattern 2: 1 Vehicle, 3 Fruits)</i>	Train Bicycle Helicopter	Tomato	Airplane	Cherry Watermelon Peach
Trial 4 <i>(Pattern 1: 1 Vehicle, 3 Fruits Pattern 2: 3 Vehicles, 1 Fruits)</i>	Airplane	Cherry Watermelon Peach	Train Bicycle Helicopter	Tomato
Trials 5, 6, and 7 (Critical Trial, Divided-Attention Trial, and Full-Attention) <i>(2 Vehicles, 2 Fruits)</i>	Car Truck	Pear Strawberry	Car Truck	Pear Strawberry

Table 4.4.

Rate of IB (%) on Critical and Divided-Attention Trials in Conditions 1-13

Condition	Unexpected Word (Primary Task)	Rate of IB on Critical Trial	Rate of IB on Divided Attention Trial	Rate of IB on Full Attention Trial
1	TRUCK (Look for Fruits)	75%	65%	20%
2	TRUCK (Look for Vehicles)	15%	15%	5%
3	GRAPES (Look for Fruits)	5%	5%	5%
4	GRAPES (Look for Vehicles)	65%	55%	15%
5	TRAFFIC (Look for Fruits)	65%	45%	25%
6	TRAFFIC (Look for Vehicles)	60%	60%	30%
7	RIDE (Look for Vehicles)	25%	30%	15%
8	RIDE (Look for Fruits)	65%	60%	25%
9	DRIVE1 (Look for Vehicles)	65%	65%	20%
10	DRIVE2 (Look for Vehicles)	45%	25%	0%
11	STEER (Look for Vehicles)	40%	40%	0%
12	GRAPES No Expectation (Look for Vehicles)	90%	70%	30%
13	GRAPES No Expectation (Look for Fruits)	10%	10%	10%

4.3. Results

Statistical analyses were conducted using SPSS v24.0.0.1 for MAC. All results were evaluated using an alpha level of 0.05. Primary-task accuracy was analysed using Mann-Whitney *U* Tests (the non-parametric equivalent of an independent samples *t*-test) and rates of inattention blindness were analysed using Chi-Square Tests. For all Chi-Square Tests performed, assumptions of raw frequency data, random sampling and independence of observations, were all met. Chi-Square Tests were two-tailed: Pearson's Chi-Square values are reported, and the effect sizes reported are the Φ coefficients. According to Cohen's (1988) criteria, when considering Φ coefficients resulting from 2x2 tables, 0.10 is a small effect, 0.30 is a medium effect, and 0.50 is a large effect.

4.3.1. Preliminary Analyses

Overall Accuracy in the Primary Task (Conditions 1-11):

To ensure that noticers and non-noticers of the critical stimulus did not differ in their initial attentional investment in the task, primary-task accuracy for reporting vehicle pictures was analysed for Trials 1-4 (non-critical trials) as well as for Trial 5 (critical trial) and Trial 6 (divided-attention trial). This accuracy analysis included seven items rather than the total of eight pictures. The image of the sail boat was removed from this accuracy analysis due to low rates of report of this stimulus (34% reported the boat) During debriefing, participants regularly mentioned that they had not considered the boat to be a vehicle; it was unclear if this reflected a failure to report or to detect the picture.

A Mann-Whitney *U* Test indicated that there was no statistically significant difference in overall primary-task accuracy on Trials 1-4 (the trials before the critical stimulus was presented) for noticers ($Md = 7$, $n = 115$) and non-noticers ($Md = 7$, $n = 105$) of the critical

stimulus on the critical trial, $U = 5403$, $p = 0.115$. There were also no significant differences when this analysis was performed separately for individual conditions and the critical trial (see Table 4.3). Median performance was near ceiling for each group. This indicates that noticers and non-noticers performed equally well on the primary task of reporting the pictures.

Trial Patterns and IB

In each experiment, two trial patterns were used (see Tables 4.1 and 4.2) to check that the order of the number of primary-task pictures presented in the non-critical trials (Pattern 1 = 1 picture, 3 pictures, 3 pictures, 1 picture; Pattern 2 = 3 pictures, 1 picture, 1 picture, 3 pictures) did not affect rates of IB. For conditions 1-11, a Chi-Square Test confirmed that trial pattern had no significant effect on IB rates on the critical trial, $\chi^2(1, n = 220) = 1.83$ $p = 0.18$.

These preliminary analyses indicated that, across all experiments participants who were instructed to look for either fruits or vehicles performed equally well on their respective primary task of naming the pictures, and trial pattern did not significantly affect the rates of IB.

Table 4.3.

Mann-Whitney U tests for primary-task accuracy (Trials 1-4 and Trial 5) for noticers and non-noticers of the critical stimulus in conditions 1-11 on the critical trial

Primary-Task Accuracy									
Condition	Critical Stimulus (Primary Task)	Trials 1-4 (Non-Critical Trials)				Trial 5 (Critical Trial)			
		Noticers Md (n)	Non-Noticers Md (n)	U	p	Noticers Md (n)	Non-Noticers Md (n)	U	p
1	TRUCK (attend fruits)	7 (5)	7 (15)	33.00	0.677	2 (5)	2 (15)	37.50	1.00
2	TRUCK (attend vehicles)	7 (17)	7 (3)	19.50	0.579	2 (17)	2 (3)	25.50	1.00
3	GRAPES (attend fruits)	7 (19)	7 (1)	6.00	1.000	2 (19)	2 (1)	9.00	1.00
4	GRAPES (attend vehicles)	7 (7)	7 (13)	35.00	0.282	2 (7)	2 (13)	45.00	1.00
5	TRAFFIC (attend fruits)	7 (7)	7 (13)	32.00	0.330	2 (7)	2 (13)	39.00	0.350
6	TRAFFIC (attend vehicles)	7 (8)	7 (12)	46.00	1.000	2 (8)	2 (12)	48.00	1.00
7	RIDE (attend fruits)	7 (7)	7 (13)	30.50	0.252	2 (7)	2 (13)	39.00	0.350
8	RIDE (attend vehicles)	7 (15)	7 (5)	30.00	0.560	2 (15)	2 (5)	37.00	1.00
9	DRIVE1 (attend vehicles)	7 (7)	7 (13)	30.50	0.252	2 (7)	2 (13)	39.00	0.350
10	DRIVE2 (attend vehicles)	7 (7)	7 (13)	30.50	0.252	2 (7)	2 (13)	39.00	0.350
11	STEER (attend vehicles)	7 (15)	7 (5)	30.00	0.560	2 (15)	2 (5)	37.00	1.00

4.3.2 Inattentional Blindness Analyses

The analysis of key interest was IB rates, that is, whether participants reported the unexpected word (see Table 4.4). Participants who reported the unexpected word and correctly indicated either its identity or location were classified as *noticers*, and those who failed to report the unexpected word were classified as *non-noticers*.

Table 4.4.
Rate of IB (%) on Critical and Divided-Attention Trials in Conditions 1-13

Condition	Unexpected Critical Stimulus Word (Primary Task)	Rate of IB on Critical Trial	Rate of IB on Divided Attention Trial	Rate of IB on Full Attention Trial
1	TRUCK (Look for Fruits)	75%	65%	20%
2	TRUCK (Look for Vehicles)	15%	15%	5%
3	GRAPES (Look for Fruits)	5%	5%	5%
4	GRAPES (Look for Vehicles)	65%	55%	15%
5	TRAFFIC (Look for Fruits)	65%	45%	25%
6	TRAFFIC (Look for Vehicles)	60%	60%	30%
7	RIDE (Look for Vehicles)	25%	30%	15%
8	RIDE (Look for Fruits)	65%	60%	25%
9	DRIVE1 (Look for Vehicles)	65%	65%	20%
10	DRIVE2* (Look for Vehicles)	45%	25%	0%
11	STEER (Look for Vehicles)	40%	40%	0%
12	GRAPES No Expectation (Look for Vehicles)	90%	70%	30%
13	GRAPES No Expectation (Look for Fruits)	10%	10%	10%

*Conditions 10 and 11 used the same critical stimulus words but different arrangements of pictures on the critical slide (see section 'Manipulating Pictures on the Critical Slide' for details)

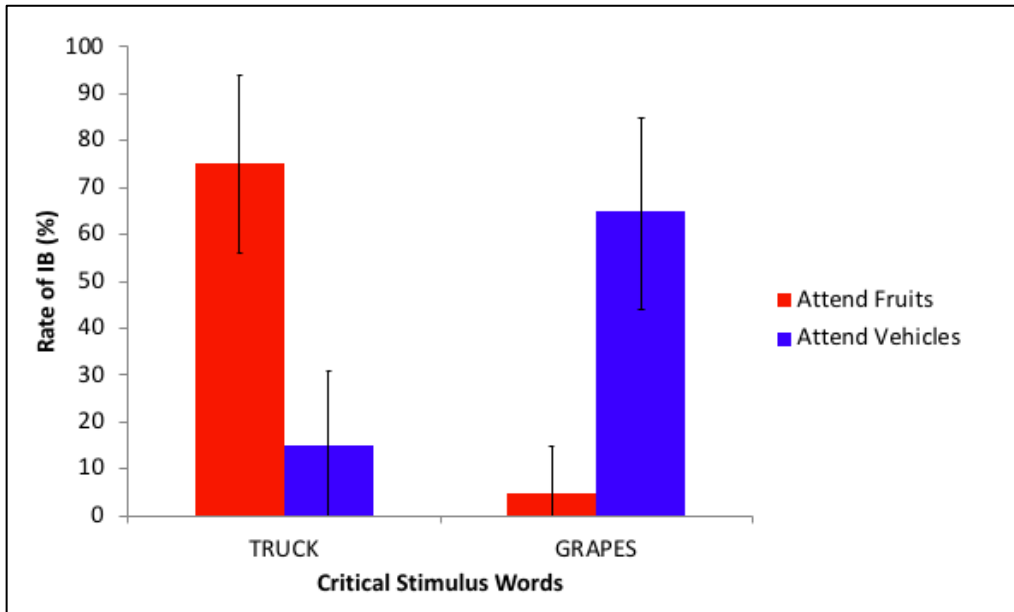


Figure 4.7. Rate of IB (%) on critical trials for conditions 1-4. Error bars represent 95% Confidence Intervals for a single proportion.

Conditions 1-4: Congruent and Non-Congruent Exemplars

Critical stimulus TRUCK: A Chi-Square Test for the critical trial indicated that IB rates were significantly lower for TRUCK when participants attended vehicle pictures (IB =15%) than when they attended fruit pictures (IB = 75%), $\chi^2(1, n =40) = 14.545, p < 0.001, \Phi = 0.603$ (large effect)- see Figure 4.7. Similarly, a Chi-Square Test for the divided-attention trial indicated that IB rates were significantly lower for TRUCK when participants attended vehicle pictures (IB =15%) than when they attended fruit pictures (IB = 65%), $\chi^2(1, n =40) = 10.417, p = 0.003, \Phi = 0.510$ (large effect).

Critical stimulus GRAPES: A Chi-Square Test for the critical trial indicated that IB rates were significantly lower for GRAPES when participants attended fruit pictures (IB =5%) than when they attended vehicle pictures (IB = 65%), $\chi^2(1, n =40) = 15.824, p < 0.001, \Phi = 0.629$ (large effect)- see Figure 4.7. Similarly, a Chi-Square Test for the divided-attention trial indicated that IB rates were significantly lower for GRAPES when participants attended fruit pictures (IB

=5%) than when they attended vehicle pictures (IB = 55%), $\chi^2(1, n = 40) = 11.905, p = 0.001, \Phi = 0.546$ (large effect).

Discussion of Conditions 1-4: Critical stimuli TRUCK and GRAPES were exemplars of each of the primary task categories: vehicles and fruits. These conditions represent a successful extension of Koivisto and Revonsuo's original paradigm to English speakers and to the categories of fruits and vehicles.

These first analyses indicated that IB rates were lower for exemplars that belonged to the semantic category of the attended items, relative to IB rates for a critical stimulus that was an unexpected exemplar word that did not belong to the attended category, and indeed belonged to the ignored category. In other words, the results of these conditions supported our hypothesis that semantically congruent exemplar words would exhibit a detection advantage compared to semantically incongruent exemplar words.

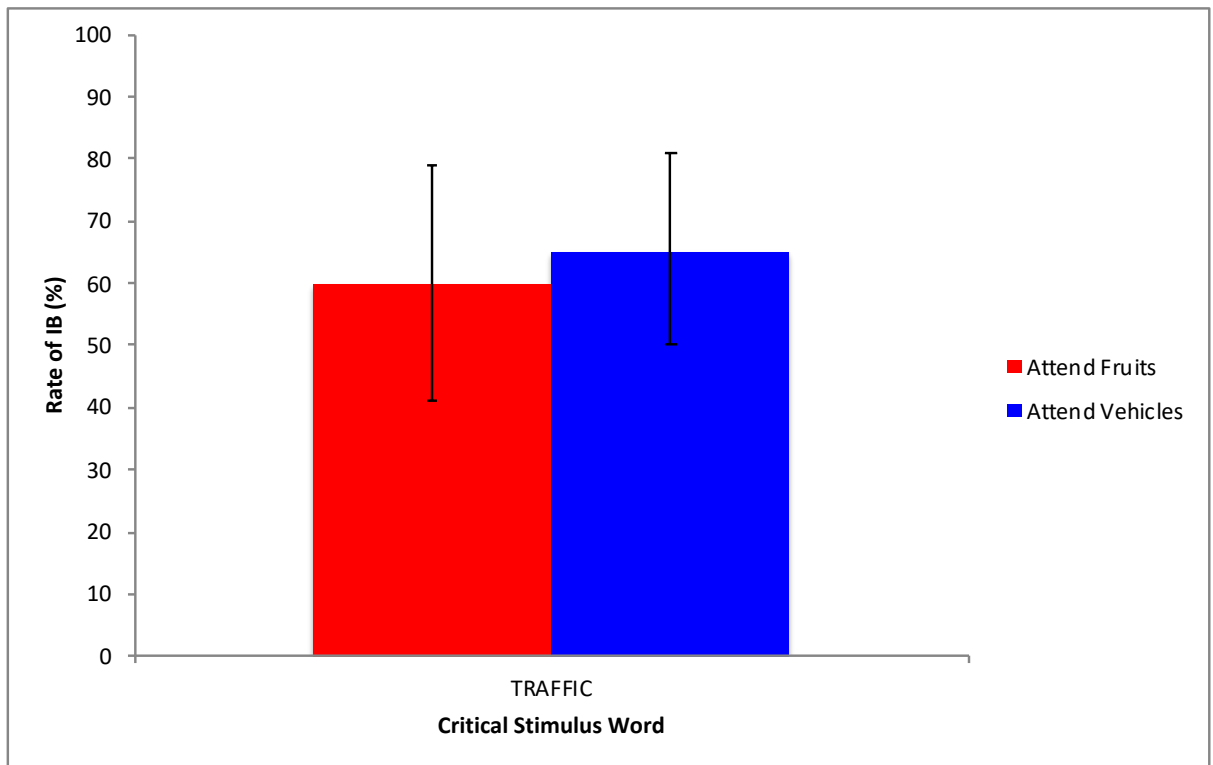


Figure 4.8. Rate of IB (%) on critical trials for conditions 5-6. Error bars represent 95% Confidence Intervals for a single proportion.

Conditions 5-6: Non-Exemplar Semantic Associate

Critical stimulus TRAFFIC: A Chi-Square test for the critical trial indicated that there was no significant difference in IB rates for TRAFFIC when attending vehicles (IB = 60%) compared to when attending fruits (IB = 65%), $\chi^2(1, n = 40) = 0.107, p = 1.000$. Similarly, a Chi-Square test for the divided-attention trial indicated that there was no significant difference in IB rates for TRAFFIC when attending vehicles (IB = 60%) compared to when attending fruits (IB = 45%), $\chi^2(1, n = 40) = 0.902, p = 0.527$ - see *Figure 4.8*.

Discussion of conditions 5-6: This condition represented an attempt to expand Koivisto and Revensuo's semantic congruency results to a word that was semantically congruent with the primary task category, but not an exemplar of that category. Previous work conducted in our lab (Mansell, 2011) led me to hypothesize that a semantic relationship would not be sufficient to modulate inattention blindness rates. This analysis indicated that a semantic relationship was not sufficient to provide a detection advantage for the unexpected stimulus. Participants were just as likely to be blind to this word regardless of whether it was related to a task relevant category.

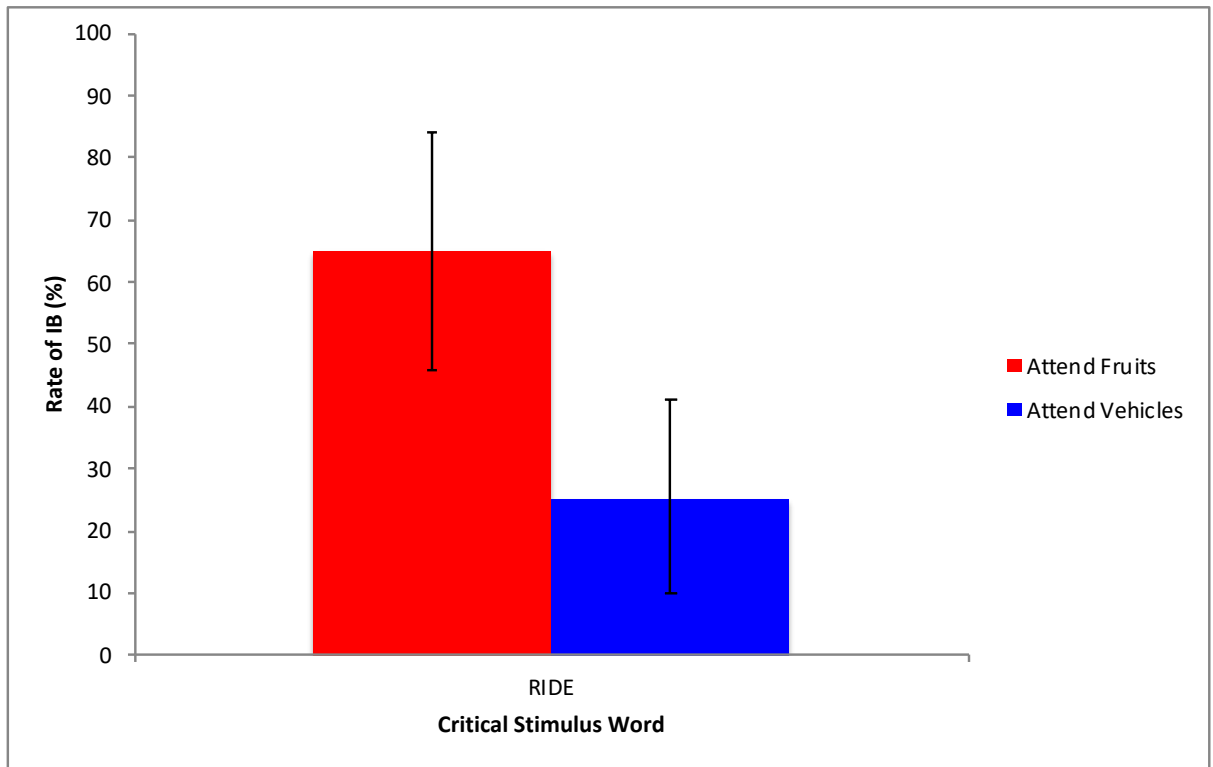


Figure 4.9. Rate of IB (%) on critical trials for conditions 7-8. Error bars represent 95% Confidence Intervals for a single proportion.

Conditions 7-8: Non-Exemplar Functionally-Associated Word

Critical stimulus RIDE: A Chi-Square Test for the critical trial indicated that IB rates were significantly lower for RIDE when participants attended vehicle pictures (IB = 25%) than when they attended fruit pictures (IB = 65%), $\chi^2(1, n = 40) = 6.465, p = 0.025, \Phi = 0.402$ (medium effect). Similarly, a Chi-Square test for the divided-attention trial indicated that IB rates were significantly lower for RIDE when participants attended vehicle pictures (IB = 20%) than when they attended fruit pictures (IB = 60%), $\chi^2(1, n = 40) = 6.667, p = 0.022, \Phi = 0.408$ (medium effect)-see Figure 4.9.

Discussion of conditions 7-8: Given that priming experiments (Lucas, 2000; Hutchinson, 2003), change blindness experiments (Triesch et al, 2003; Symes et al., 2008) and neurophysiological studies (Moss & Tyler, 1995; Humphreys &

Riddoch, 2001) had indicated that functional relationships can activate semantic associations between words that lead to increased awareness, I had hypothesized that the semantic congruency effect might extend to words that were functionally related to the primary task condition. These analyses supported this hypothesis by demonstrating that participants who were attending pictures of vehicles had significantly lower IB rates for the word RIDE compared to participants who were attending pictures of fruits. In subsequent conditions, I attempted replicate this finding for different words that were also functionally associated with vehicles.

Conditions 9-11: Attempts to Expand Semantic Congruency Effects to Additional Non-Exemplar Functionally-Associated Words¹³

In an attempt to replicate our findings for functionally associated semantic congruency effects, I tested two additional words that were functionally associated with vehicles, DRIVE and STEER. Rates of inattentional blindness for participants presented with these words while looking for vehicles did not appear to exhibit a semantic congruency effect (see Table 4.4). Indeed, our analyses indicated that rates of inattentional blindness for DRIVE and STEER were not significantly different from inattentional blindness rates of participants who were looking for vehicles and were presented with the semantically incongruent word GRAPES.

Critical Stimulus DRIVE: A Chi-Square test for the critical trial indicated that there was no significant difference in IB rates for DRIVE when participants were attending vehicles (IB = 65%) compared to GRAPES when participants were attending vehicles (IB = 65%), $\chi^2(1, n = 40) = 0, p = 1.000$. Similarly, a Chi-Square

¹³ Due to limitations of cost and time, I did not run the words DRIVE and STEER in 'Look for Fruits' conditions. Given the results of conditions 9 & 10 compared to conditions 2 and 3, it was extremely unlikely that a comparison with 'Look for Fruits' conditions would result in significant differences.

test for the divided-attention trial indicated that there was no significant difference in IB rates for DRIVE when participants were attending vehicles (IB = 65%) compared to GRAPES when participants were attending vehicles (IB = 55%), $\chi^2(1, n = 40) = 0.107, p = 1.000$.

Critical stimulus STEER: A Chi-Square test for the critical trial indicated that there was no significant difference in IB rates for STEER when participants were attending vehicles (IB = 40%) compared to GRAPES when participants were attending vehicles (IB = 65%), $\chi^2(1, n = 40) = 2.51, p = 0.21$. Similarly, a Chi-Square test for the divided-attention trial indicated that there was no significant difference in IB rates for STEER when participants were attending vehicles (IB = 40%) compared to GRAPES when participants were attending vehicles (IB = 55%), $\chi^2(1, n = 40) = 2.51, p = 0.21$.

Conditions 9 & 11: Manipulating pictures on the critical slide

Given the fact that RIDE appeared to exhibit a semantic congruency effect while DRIVE did not, I decided to test the possibility that the items on the critical trial (bike and bus) were specifically priming the word RIDE. I ran an additional condition, with the pictures shuffled so that the critical trial included the more DRIVEable vehicles car and truck.

Critical stimulus DRIVE with bike & bus on the critical slide v.

DRIVE with car and truck on the critical slide: A Chi-Square test for the critical trial indicated that there was no significant difference in IB rates for DRIVE when the critical slide included a bike and bus (IB = 65%) compared to when the critical slide included a car and truck (IB = 45%), $\chi^2(1, n = 40) = 0.204, p = 0.341$. However, a Chi-Square test for the divided-attention trial indicated that IB rates were significantly lower for DRIVE when the critical slide included the car and truck

(IB = 25%) than when critical slide included the bus and bike (IB = 65%), $\chi^2(1, n = 40) = 6.465, p = 0.025, \Phi = 0.402$ (medium effect)- see *Figure 4.10*.

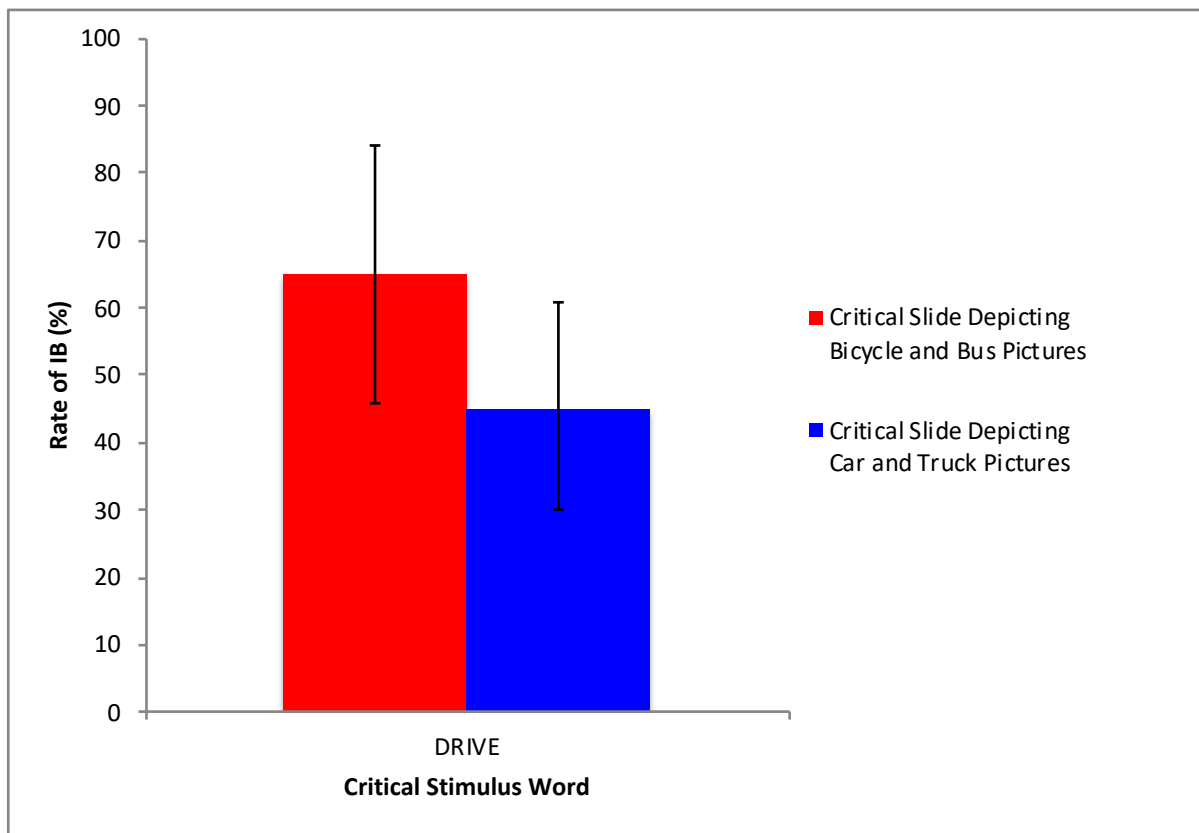


Figure 4.10. Rate of IB (%) on critical trials for conditions 9-10. Error bars represent 95% Confidence Intervals for a single proportion.

Conditions 12-13: Controlling for participants' expectations

I also ran two additional experimental conditions designed to control for the influence of participants' expectations about the stimulus display. In conditions 1- 11, as part of their task instructions, participants completed a paper 'practice' trial. They were shown an example stimulus display—four line-drawings of fruits and vehicles arranged around a fixation cross, then each of the 4 non-critical trials also featured four items arrayed around the fixation cross.

Exposure to the practice trial and the non-critical trial may have served as perceptual primes, decreasing the likelihood that participants would subsequently notice when the cross was substituted for the written word on the critical trial.

Participants in conditions 12 and 13, the ‘No Expectation’ conditions, were not shown an example display when they received their instructions, rather they were simply shown two pairs of pictures (a sled alongside a tank and a lemon alongside a raspberry). They were told that “pictures of vehicles will look something like this, and pictures of fruits will look something like this.” Furthermore, rather than completing four non-critical trials prior to the critical trial, the first trial that participants in the ‘No expectation’ conditions saw was the critical trial. Aside from the modification of the instructions and the elimination of the non-critical trials, the ‘No expectation’ conditions were otherwise identical to the 11 preceding conditions.

Critical stimulus GRAPES (no expectation): A Chi-Square Test for the critical trial indicated that IB rates were significantly lower for GRAPES when participants attended fruit pictures (IB =10%) than when they attended vehicle pictures (IB = 90%), $\chi^2(1, n =20) = 13.82, p < 0.001, \Phi = 0.80$ (large effect). Similarly, a Chi-Square Test for the divided-attention trial indicated that IB rates were significantly lower for GRAPES when participants attended fruit pictures (IB =10%) than when they attended vehicle pictures (IB = 70%), $\chi^2(1, n =20) =7.50, p =0.006, \Phi = 0.61$ (large effect).

4.4. General Discussion

Despite most peoples’ intuition that they experience a richly vivid and uninterrupted view of the world around them, the amount of information that our visual systems are bombarded with is actually overwhelming. Attention allows us to selectively process this information, helping to ensure we notice what is most important to us. But as a consequence, many stimuli will fail to enter our awareness. And, most of the time, we remain unaware of just how unaware we are. The study of inattention blindness grants researchers a glimpse into this vast unseen world. The

present experiments demonstrate that, while meaning does indeed shape seeing, not all types of meaning will shape seeing in the same ways. Participants in our experiment were presented with unexpected written words while they engaged in a picture-naming task. Because the words did not share perceptual features with pictures, this allowed us to isolate the influence of semantic relationships on rates of inattentional blindness. We investigated three distinct types of semantic relationships- taxonomic, thematic, and functional. Of these, only congruent taxonomic relationships appeared to consistently modulate inattentional blindness. Overall, rates of inattentional blindness for the unexpected words were between 60% and 80%. These rates are notable given that the unexpected words were presented at fixation for more than a full second. The only conditions that resulted in consistently lower rates of inattentional blindness were those conditions in which the unexpected words were both semantically congruent and taxonomically related to the pictures that the participant had been instructed to look for. Participants exhibited lower rates of inattentional blindness for the unexpected word GRAPES when they were instructed to look for fruit pictures, and TRUCK when they were looking for vehicle pictures. In each of these instances, IB rates were reduced to 10% or 15%. These results provide a powerful demonstration of the ‘semantic congruency effect’ (Koivisto & Revonsuo, 2007). For GRAPES and TRUCK, each semantically congruent condition was paired with a semantically incongruent condition. Across these conditions, the stimuli were identical and the only variable that changed between participants was the primary task instruction. For example, when the unexpected word was GRAPES, participants who were told to look for fruit pictures and participants who were told to look for vehicle pictures were presented with the exact same stimuli. Therefore, the difference in inattentional blindness rates between these two groups is attributable to the semantic relationship between the task instructions

and the unexpected word. However, this semantic congruency effect did not necessarily extend to words that were thematically or functionally congruent. While the participants were significantly more likely to see the word RIDE when it was semantically congruent with the primary task, the rates of inattentional blindness for semantically congruent unexpected words TRAFFIC, DRIVE, and STEER were similar to the rates of inattentional blindness for conditions when the unexpected words were semantically incongruent with the primary task pictures (e.g. when the unexpected word was TRUCK and the participants were looking for fruits).

One of the first theoretical frameworks developed to explain the failures of visual awareness that would later be characterized as inattentional blindness was Neisser's Perceptual Cycle (e.g. Neisser, 1978). Neisser adopted an information processing approach to describe how images projected on the retina could be processed to the level of conscious awareness. Crucially, he suggested that the process of exploring and picking-up environmental information was partially driven by anticipation-based schemata. In Neisser's view, schema were internal structures that served to facilitate perceptual exploration. This perspective has been adapted by subsequent researchers (e.g. Simons, 2000; Most, Scholl, Clifford, & Simons, 2005; Most 2013) to accommodate contemporary developments in inattentional blindness and attentional set theory. Attentional set has been conceptualized as the top-down process that observers can 'tune' based on their current task goals. This tuning serves as a guide to pre-attentive exploration and facilitates perception, like Neisser's proposed anticipation-based schemata. This process is well established for low-level perceptual features (e.g. Simons & Chabris, 1999; Most, Simons, Scholl, Jimenez, Clifford, & Chabris, 2001; Most et al., 2005). For example, in the iconic Invisible Gorilla Paradigm (e.g. Simons & Chabris, 1999), participants who were instructed to

attend a video of a basketball game were more likely to notice the unexpected appearance of an additional person wearing a black gorilla costume, if they had been instructed to attend players wearing black t-shirts, compared to when they were instructed to attend players wearing white t-shirts. The unexpected object had a low-level perceptual feature (black color) that corresponded with the observers' task-based attentional set (look at players wearing black), thus observers were more likely to have their attention captured by the gorilla, even though they were not actively looking for it specifically. This implies that observers are able to process the color of an unexpected object before they become explicitly aware of that object. We now know that attentional set can also facilitate detection of unexpected objects based on their semantic features. These findings suggest that unexpected stimuli can be processed relatively deeply prior to awareness. In our experiment, and in Koivisto and Revonsuo's (2007) paradigm, the unexpected stimuli consisted of written words and the participants' primary task was a picture-naming task involving line drawings. In the conditions where the semantic congruency effect appears to modulate inattention blindness, observers must first detect that the fixation cross has been replaced with an unexpected object, they must recognize that object as a collection of letters, read the letters as a word, and associate the semantic meaning of that word with their primary picture-naming task, all before becoming explicitly aware of the word!

Our results represent a novel contribution to the investigation of category-based attentional set. Previous experiments (Koivisto and Revonsuo, 2007; 2009; Most et al., 2011), explored semantic congruency in general, but to our knowledge this is the first study of inattention blindness to directly contrast the influence of different types semantic relationships. While we did not find evidence that any other

type of semantic relationship other than taxonomic relationships will modulate inattentional blindness, it remains possible that other combinations of primary task categories and unexpected words might influence inattentional blindness rates. Our paradigm, adapted from Koivisto and Revonsuo's (2007) study, represents an exciting tool to help cognitive scientists and language researchers to map the cognitive structure of semantic categories. The fact that the paradigm appears to provide useful data when the entire experiment consists of only a single slide means that this is also a highly efficient method of collecting inattentional blindness data. Also of note is the fact that a significant minority of participants failed to detect the critical stimulus on my full attention trials- traditionally the full attention trial was used as a control to demonstrate that participants were physically capable of detecting what might have been a difficult to detect critical stimulus; however, in the case of my paradigm, the word presented on the screen for 1200 milliseconds is indisputably *very possible* for the human eye to perceive. This begs the question as to just how participants were able to remain inattentionally blind on the full attention trial- perhaps they were unable to relinquish their previously established attentional set despite the experimenter's instructions for them to abandon their previous primary task. Such findings support recent calls by White, Davies, & Aimola Davies for researchers to reconsider the theoretical significance of full attention trials in inattentional blindness paradigms. Broadly speaking, investigations of semantic congruency and inattentional set have the potential to further elucidate how bottom-up stimulus properties interact with top-down attentional factors to modulate awareness. This field of inquiry has a variety of practical implications beyond laboratory paradigms. Given that humans are exposed to a vast amount of perceptual input in the course of day-to-day activities; attentional set allows us to tune our awareness more precisely to stimuli that are relevant to our goals. We must be able to

filter-out irrelevant distractions, while still being able to accommodate relevant but unexpected events. Setting attention to meaning is arguably something that occurs when we engage in tasks like driving a car or surfing the Internet. Understanding how attentional set for meaning can influence awareness, might have important practical implications for a range of problems from road safety to advertising.

4.5 IB and Visual Metacognition:

The Problem of Inattentional Blindness or Everyday Visual Anosognosia

Mack and Rock's (1998) conclusion that there can be "no conscious perception without attention" (page 228) is profoundly counterintuitive. It directly contradicts the conventional idea that one simply needs to direct one's gaze towards something to see it (e.g. Noe, 2002; Simons, 2011). Indeed, some of the earliest work demonstrating inattentional blindness (Münsterberg, 1907; Cornell 1960; Niesser, 1973) was largely ignored itself for nearly three decades, even within the scientific community of perception researchers. The reason for this oversight may be that these findings directly contradict intuitive ideas about looking and seeing (e.g. Rensink as quoted, in Carpenter, 2001; Chabris & Simons, 2010).

Attention researchers have suggested that the concept of inattentional blindness has potentially serious implications outside of the lab and in the context of people's day-to-day life (e.g. Chabris & Simons, 2011). It seems reasonable to argue that the general population might be suffering from a large-scale form of confirmation bias. Perhaps we do often miss unanticipated objects and events that appear to us, but often these failures to notice may not be critical to our day-to-day activities and goals. Hence these failures to notice themselves pass unnoticed. In

contrast, the act of noticing, by definition, will enter into someone's conscious awareness. This could well lead to people overestimating their ability to detect unexpected objects and events. Surveys of the general public have shown that the majority of respondents believe that "People generally notice something in their field of view, even if they're paying attention to something else" (Simons & Chabris, 2011; 2012).

During the course of the inattention blindness experiments described in chapter 5, one of the most interesting elements of the data collection was the process of debriefing each participant. From the earliest pilot experiments, it became apparent that many participants did not believe that it was possible for anyone to fail to detect the critical stimuli words during the critical trials. Participants who failed to see the words were often visibly alarmed that they could fail to detect what they thought was an obvious stimulus. On more than one occasion participants would request that I re-run the experimental software. Then, after they watched stimuli flash across the screen, they sometimes remained skeptical that the word they saw had been present during their first run through.

For every single trial conducted, the experimenter (myself) was always seated directly behind the participant. I had a clear view of the monitor on which the stimuli were presented. On a personal note: even after running the experiment, hundreds of times, it was consistently strange to watch the participants fail to detect the words that were presented for over a second on a few inches from their faces, in the center of the computer screen, where they were fixing their gaze in compliance with the experimental instructions. The experience was reminiscent of performing a magic trick. Certain magic tricks, particularly slight-of-hand-based effects, can sometimes

feel as though they are bound fail inevitably, and the fact that they work can be a consistent surprise to the performer.

Following my initial pilot experiments, I introduced a short follow-up questionnaire, intended to briefly assess the participants' metacognitive evaluations of their own experiences with the experimental paradigm. After each of the 220 participants in conditions 1-11 had completed the full attention trial as described in chapter 4, they answered three additional questions.

First, the experimenter produced an A4 sized (210cm x 297cm) printed screen shot of the critical trial slide that participants had just been presented with on the computer monitor. After presenting the participants with the print-out, the experimenter asked the following yes or no question:

“Do you believe that the last three slides that you saw all contained a large word in the center of the pictures- like this?”

Next, participants were asked:

“Have you ever heard of “inattentional blindness.”

Participants who answered ‘Yes’ were asked to briefly describe what inattentional blindness was; this answer was only recorded if they were able to provide some semblance of a definition or refer to an experiment or demonstration.

For example, they might say that “it’s when you look at a thing but don’t notice it” or that “it’s like the video with the gorilla” or the “commercial with the bear costume.”¹⁴

Overall, 64% of the participants who were inattentionally blind to the critical stimulus ($n = 105$) answered that they did not believe that word had been present on all three of the last slides that they just saw. They expressed explicit disbelief that the word could have been presented without them seeing it. Across all experimental conditions, familiarity with the concept of inattentional blindness did not appear to predict whether or not participants would notice the critical stimuli. 38% of participants (83 of the total 220) were able to demonstrate that they were familiar with the term inattentional blindness (Table 4.5). A Chi-Square test indicated that there was no significant association between expressed knowledge of IB and actual rates of IB, when IB rates between participants who were familiar with the idea of inattentional blindness (IB = 59%) were compared to participants who reported that they had never heard of the term (IB = 48%), $\chi^2(1, n = 220) = 2.44, p = .128$.

Table 4.5
Cross-Tabulation of Knowledge of IB and Rates of IB on the Critical Trial

		IB on the critical trial?	
		No	Yes
Knew about IB?	No	66 (30%)	71 (32%)
	Yes	49 (23%)	34 (15%)

¹⁴ In 2008 Transport for London released a video based on the Simons and Chabris’ Invisible Gorilla Paradigm, the video was played in cinemas around the UK and uploaded to YouTube (McVeigh, 2008)

Additionally, familiarity with the concept of IB did not seem to significantly influence participants' beliefs about their experiences during the experiment (see Table 4.6). Of participants who were inattentionally blind to the stimulus at least once, a Chi-Square test indicated that there was no significant association between knowledge of IB and belief that IB had occurred when belief rates between participants who were familiar with the idea of inattentional blindness (71% of whom believed that the word was presented 3 times) were compared to participants who reported that they had never heard of the inattentional blindness (64% of whom believed that the word was presented 3 times), $\chi^2(1, n = 105) = 1.35, p = .288$.

Table 4.6

Cross-Tabulation of Knowledge of IB and Expressed Belief that Unexpected Word Stimulus had been Presented Three Times Among Participants Who Failed to Report the Word on the Critical Trial

		Believed that critical word appeared 3x?	
		No	Yes
Knew about IB?	No	46 (43%)	18 (17%)
	Yes	25 (23%)	16 (15%)

Mack and Rock (1998) had asserted that one of the key aspects of their inattention paradigm was that it allowed for only one trial per each participant, and that each new experiment “demands a new naïve group of participants” (p. 8). Traditionally, subsequent researchers have either explicitly excluded any participants who have expressed any general knowledge of IB or at least specifically noted that their participants were naïve (e.g. Cartwright-Finch & Lavie, 2007; Memmert, 2006; Memmert, Simons, & Grimme, 2009; Most, Scholl, Clifford, & Simons, 2005; Most, Simons, Scholl, & Chabris, 2000; Most et al., 2001; Simons & Chabris, 1999; Simons & Jensen, 2009; Wayand, Levin, & Varakin, 2005; White & Aimola Davies, 2008).

Our results are in line with a small body of past research, which has established that rates of noticing unexpected stimuli in an inattention blindness paradigm are not necessarily predicted by a viewer's general knowledge about inattention blindness, unless that knowledge is related to a specific stimulus within a particular paradigm. Simons (2010) created a modified version of the Invisible Gorilla Paradigm (Simons & Chabris, 1999; Neisser & Becklan, 1975). The video they used was similar to the original video stimulus from the relatively well-known 1999 experiment, except that, in addition to a person in a gorilla costume appearing during the game, the background behind the players changed color and one of the player's wearing a black t-shirt left the game by walking off the screen. Participants who were familiar with the original paradigm were actually less likely to notice these additional anomalies than participants who were naïve to the original experiment. In another series of experiments, Beanland and Pammer (2010) reported that participants' general knowledge of IB did not predict their noticing rates for a critical stimulus on a dynamic IB task using simple geometric shapes— IB information only influenced participants rates of noticing when the IB information was presented to participants immediately before they completed the IB paradigm.

Research in the related domain of change blindness is also relevant to my results. Change blindness is another kind of attentional blindness. The phenomenon is similar to IB except that it specifically relates to changes that occur within scenes; participants can be surprisingly likely to fail to detect these changes when they are accompanied by a visual disruption (e.g. Rensink, O'Regan & Clark, 1997). These failures of awareness are so surprising that some researchers have coined the phrase *change blindness blindness* (e.g. Beck, Levin, & Angleone, 2006; Levin, Momen, Drivdahl, Simons, 2010) to describe the metacognitive error wherein participants

overestimate their own change detection abilities (i.e. underestimate their propensity to be change blind). In parallel, my results can arguably be considered as a form of inattentional blindness blindness.

The experience of magic tricks suggests several interesting parallels here. Indeed, psychologists have long known that magicians' techniques can be effectively used for "rendering invisible a spectacle which is perfectly visible to all eyes" (Binet, 1894, p. 564). The fact that people do not believe that they are capable of failing to see certain stimuli and are then confronted during a debriefing procedure with the reality that they have indeed failed to notice a particular stimulus is conceptually similar to the 'illusion of impossibility' associated with magic tricks (e.g. Ortiz, 2014). That is to say, participants 'know' they could not have failed to detect the stimulus, but then they are forced to acknowledge the fact that they failed to detect it. Furthermore, contemporary experiments that use paradigms derived from magic tricks have provided a variety of evidence that viewers can exhibit both inattentional blindness (Kuhn & Tatler 2005; Kuhn, Tatler, Findlay, & Cole, 2008; Barhard & Goldinger, 2015) and change blindness (Smith, Lamont, & Henderson, 2012; 2013) even within regions where they have fixated their gaze.

Overall, the present results raise interesting questions about the relationship between abstract knowledge of a psychological phenomenon and actual task performance. My belief related question, asking participants if they thought the word had appeared on the 'last three slides' was arguably somewhat convoluted. And these present results should be considered somewhat cautiously. Ideally, I would have been able to directly question participants about belief that the word had appeared on the critical trial, immediately after the critical trial itself. However, this would have invalidated subsequent divided and full attention trials, hence the compromised

wording of the final question discussed in this chapter. Despite these limitations, this questionnaire marks the first empirical attempt to examine the metacognitive evaluations of participants who just completed an inattention blindness task, and it seems clear that further investigation is warranted into this relationship between belief, metacognition, and awareness, as it has serious implications for the practical applications of perception research.

Chapter 5

The Phantom Vanish

Magic Trick

**An Investigation of the
Disappearance of a Non-Existent Object
in a Dynamic Visual Scene**



Drawing inspiration from sleight-of-hand magic tricks, I developed an experimental paradigm to investigate whether magicians' misdirection techniques could be used to induce the misperception of "phantom" objects.¹⁵ While previous experiments investigating sleight-of-hand magic tricks have focused on creating false assumptions about the movement of an object in a scene, my experiment investigated creating false assumptions about the presence of an object in a scene. Participants watched a sequence of silent videos depicting a magician performing with a single object. Following each video, participants were asked to write a description of the events in the video. In the final video, participants watched the Phantom Vanish Magic Trick, a novel magic trick developed for this experiment, in which the magician pantomimed the actions of presenting an object and then making it magically disappear. No object was presented during the final video. The silent videos precluded the use of false verbal suggestions, and participants were not asked leading questions about the objects. Nevertheless, 32% of participants reported having visual impressions of non-existent objects. These findings support an inferential model of perception, wherein top-down expectations can be manipulated by the magician to generate vivid illusory experiences, even in the absence of corresponding bottom-up information.

¹⁵ Portions of this chapter have previously been published as a peer-reviewed article (Tompkins, Aimola-Davies, Woods, 2016).

5.1 Introduction

The performance of magic is based on practical and theoretical knowledge of psychology (see Gregory, 1982; Kuhn, Amali, & Rensink, 2008; Macknick et al., 2008; Kuhn & Rensink, 2014). Performance magic, particularly sleight-of-hand or ‘conjuring,’ represents a rich resource for experimental psychologists. In particular, sleight-of-hand magic tricks provide a unique opportunity to investigate illusory perceptions of complex dynamic scenes. Magicians have spent millennia informally experimenting with perception, attention, and memory (e.g., Christopher & Christopher, 1973; Thomas, Didierjean, Maquestiaux, & Gygax, 2015), and theoretical writings on magic, dating back hundreds of years (e.g., Scot, 1584; Hodgeson, & Davey, 1887), anticipated recent scientific accounts of psychological phenomena.

Empirical investigations of magic played a critical role in the establishment of Experimental Psychology as a scientific discipline (e.g., Wundt, 1879; Pettit, 2013; Figure 4.1, see also Chapter 2), and early psychologists have written about the psychology of magic tricks (Jastrow, 1888, 1896; Dessoir, 1893; Binet, 1894; Triplett, 1900; see also Lamont, 2010; Thomas, Didierjean, & Nicolas, 2017). However, performance magic was largely ignored by the scientific community throughout the 20th century (Hyman, 1989). The first scientific study of magic to implement physiological measurements of adults perceiving magic effects was not conducted until 2005. Kuhn and Tatler (2005) used an eye-tracking paradigm to examine participants who watched a simple magic trick involving the apparent disappearance of a cigarette and a lighter. By integrating eye-tracking with sleight-of-hand-based stimuli, this experiment arguably marks one of the first scientific examinations of magic to move beyond the domain of observations, reviews, and opinion pieces into

formal empirical investigation. This trend towards a ‘science of magic’ has continued throughout the past decade, with researchers adapting magic tricks to investigate a wide variety of cognitive mechanisms. The present study builds upon previous research by introducing a novel paradigm designed to test how magicians can manipulate the way spectators perceive objects in dynamic scenes. While previous studies (e.g., Kuhn & Land, 2006; Beth & Ekroll, 2015) have demonstrated that magic tricks can cause spectators to make false assumptions about the movement of objects in a scene, the current study takes this a step further by testing whether misdirection can cause spectators to make false assumptions about the presence of objects in a scene.

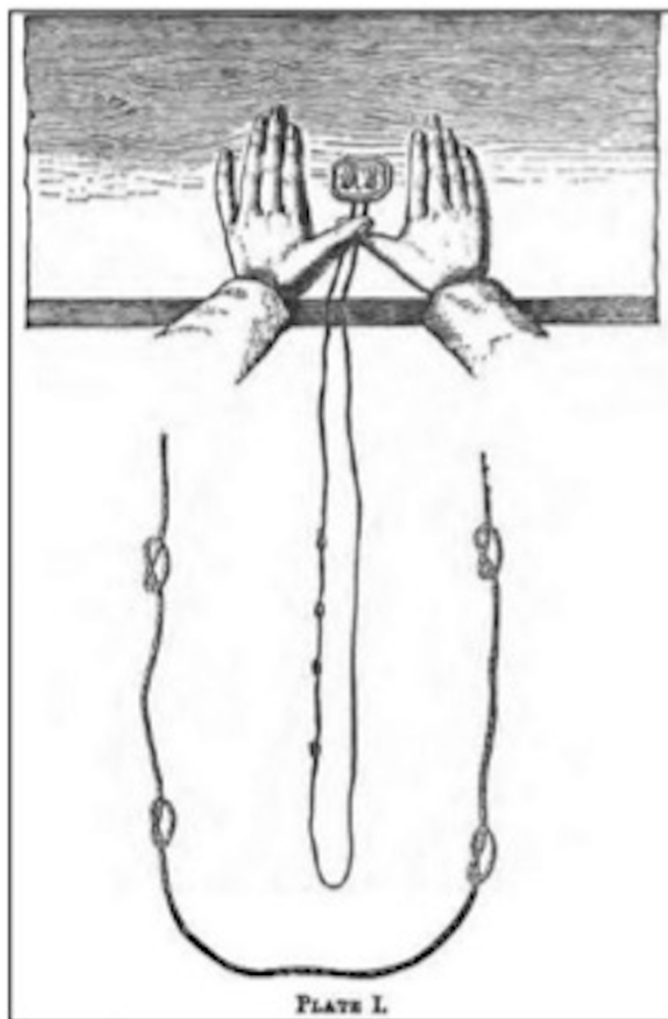


Figure 5.1. Impossible Knots in an Endless Cord (Zöllner, 1878). Using this experiment, Professor Johann Zöllner described how a professional spirit medium could cause knots to form in a length of rope, even though the ends of the rope were sealed. Zöllner asserted that this was evidence of a supernatural power unexplained by modern science. Wundt (1879) argued that it was trickery. While Wundt was in the process of establishing the first Experimental Psychology Laboratory at the University of Leipzig, he became embroiled in a debate about the scientific value of investigating alleged supernatural phenomena. His colleagues, including Johann Zöllner, Gustav Fechner and Ernst Weber, believed that they had discovered a new branch of ‘transcendental’ physics, while Wundt maintained that they had been deceived by magic tricks or ‘jugglery’. This controversy gave rise to a series of articles by early experimental psychologists looking to investigate the relationship between illusory perception and beliefs (Jastrow, 1888, 1896; Dessoir, 1893; Binet, 1894; Triplett, 1900).

Magicians have written extensively about the theory and practice of magic (e.g., Houdin, 1868/1881; Professor Hoffman, 1876; Maskelyne & Devant, 1911), and it is useful to adopt some of their informal terminology when describing empirical investigations involving magic (e.g., Lamont & Wiseman, 1999). In this terminology, a ‘trick’ consists of both an ‘effect’ and a ‘method’, effect referring to the subjective experience of the spectators, and method referring to the mechanisms by which the effect is achieved (Figure 5.2., see Rensink & Kuhn, 2015; Lamont, 2016 for a discussion of classifying magic tricks based on methods and effects). For a trick to be successful, the performer must disguise the true method behind the effect, creating an ‘illusion of impossibility’ (e.g., Nelms, 1969; Ortiz, 2006); the manipulations used to accomplish this are referred to as ‘misdirection.’

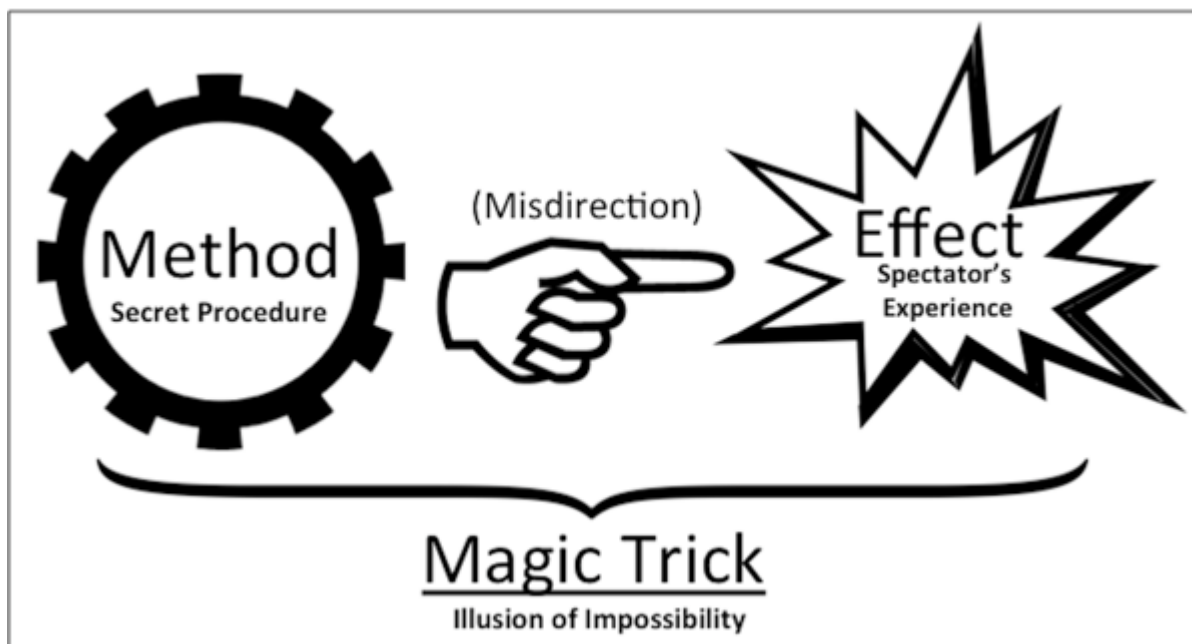


Figure 5.2. Performing a magic trick involves using a ‘Method (Secret Procedure)’ to produce an ‘Effect (Spectator’s Experience)’. Misdirection refers to the manipulations used to disguise the true method of the trick while simultaneously emphasizing the effect (adapted from Lamont & Wiseman, 1999).

Misdirection is a particularly elusive term (e.g., Lamont & Wiseman, 1999; Kuhn, Caffaretti, Teszka, & Rensink, 2014). To date, most psychological considerations of misdirection have focused almost exclusively on how misdirection can be used to conceal objects and events from spectators (e.g., Kuhn & Findlay, 2010; Memmert, 2010; Lamont & Wiseman, 1999). Existing paradigms tend to focus on how to prevent spectators from detecting ostensibly visible elements of the methods behind magic effects. These failures to see have been associated with phenomena such as inattentional blindness (Kuhn & Tatler, 2005; Barnhart & Goldinger, 2014) and change blindness (e.g., Johansson et al., 2005; Smith et al., 2012, 2013).

But misdirection does not only involve inducing failures to see, it can also involve inducing misperceptions of illusory objects. The one notable exception to this trend of focusing on concealment is the empirical investigation of the Vanishing Ball Illusion. This effect was first introduced into the psychological literature by Dessoir (1893), an early psychologist and amateur magician (Whaley, 2006). Dessoir described how a magician might induce the misperception of an illusory object – by tossing an orange into the air two times, then secretly dropping the orange into his pocket while pantomiming a third toss with his empty hand. Spectators would misperceive the orange leaving the magician's hand and disappearing into the air on the third toss.

Triplett (1900) conducted actual informal experiments with school children, in which he performed a similar trick using a tennis ball. About half the children reported that they had perceived the ball rise towards the ceiling and then vanish. This Vanishing Ball Illusion has been adapted by Kuhn and Land (2006), who demonstrated that 63% of adult observers reported an illusory ball. They also argued

that eye-tracking recordings suggested that social cues from the magician contributed to the illusion, that is, spectators who experienced the Vanishing Ball Illusion (the misperception of an illusory ball) looked to the magician's eyes and were misdirected by his gaze as he looked upwards during the false throw. Subsequent studies have demonstrated that this magical effect remains relatively robust even without deceptive social cues (Thomas & Didierjean, 2016; for a broader discussion of the role of social cues in magic see Cui, Otero-Milan, Macknik, King, & Martinez-Conde, 2011; Tachiabana, 2014). More recent research has demonstrated that the illusion can also be induced even in the absence of the initial 'real' throws (Kuhn & Rensink, 2016).

Other studies involving sleight-of-hand magic tricks have used the false transfer method to examine the degree of 'magicalness' of performances. Beth and Ekroll (2015) showed participants a series of videos of a magician performing magic tricks that included several 'vanishes.' The effect was that a poker chip seemed to inexplicably disappear, and this was accomplished with a method known as a false transfer— the magician pretended to pass a poker chip from one hand to his other, while secretly retaining it in his first hand. By manipulating the timing between the moment of the false transfer and the revelation that the poker chip was not in the magician's hand, they found that participants would rate the quicker revelations of the empty hand as being relatively more magical. The authors suggested that such vanishing effects could be associated with amodal perception –perceptual experiences that are not directly drawn from any sensory modality (see also Nanay, 2005; Barnhart, 2010; Ekroll, Sayim, & Wegmans, 2013, 2017). In particular, they highlight the phenomena of both modal and amodal completion (see Figure 5.3).

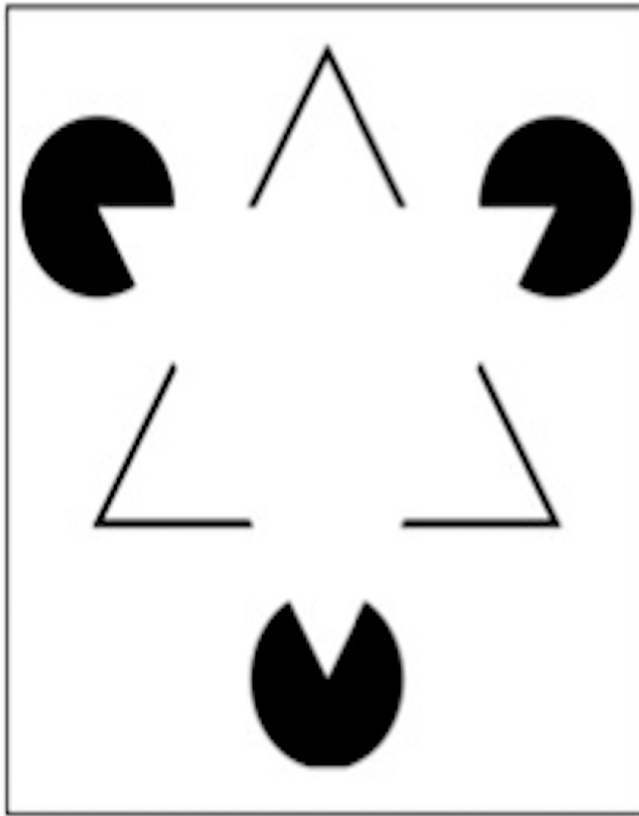


Figure 5.3. Kanizsa Triangle Illusion (Kanizsa, 1976). This illusion demonstrates modal and amodal completion. Objectively this image consists of three ‘pac-man’ shapes and three ‘V’ shapes. Modal completion refers to the shape that is perceived to be occluding the shapes behind it, and amodal completion refers to the shapes that are perceived to be occluded. The process of modal completion allows the viewer to perceive a white downward-pointing triangle, while the process of amodal completion allows the viewer to perceive the V shapes as the black outline of an upward-pointing triangle, and to perceive the three pac-man shapes as complete discs. Both of these processes fall into the category of amodal perception because they relate to perceptual experiences that are not drawn directly from the objective visual information.

While many studies of sleight-of-hand magic tricks have focused on the role of spectators’ perceptions, an additional small body of literature focuses specifically on the physical actions of the magician’s hands. For example, one study (Cavina-Pratesi, Kuhn, Ietswaart, & Milner, 2011) has demonstrated that practicing magicians are significantly more skillful at pantomiming actions compared to control participants (non-magicians). When asked to pantomime the action of picking up an object, control participants made hand motions that were notably different from genuine grasping gestures. In contrast, the fake grasping gestures of the magicians were more kinematically similar to their genuine grasping actions. Such expertise contributes to the deceptiveness of sleight-of-hand performances (Phillips, Natter, & Egan, 2015), and surveys of professional magicians indicate that they place a particularly high value on pantomimic expertise (e.g., Rissanen, Pitkänen, Juvonen, Kuhn, & Hakkarainen, 2014).

The present study extends previous research on the false transfer method and the Vanishing Ball Illusion by introducing a novel magic trick, adapted by the first author. The Phantom Vanish Trick was created to investigate the idea that participants can form vivid illusory impressions of objects in response to magic performances. The method is inspired by a sleight-of-hand technique historically referred to as a 'bluff vanish' (e.g., Shephard, 1950; Bobo, 1952). In the original method, the magician begins by clearly and openly showing the spectators that he is holding a handful of mixed coins. Then, with his other empty hand, he reaches into the handful of coins and pantomimes the action of taking away a single coin. The magician does not actually take anything from the handful of coins, but he does (falsely) verbally indicate to the spectators that he has taken one of the coins. Next the magician disposes of the 'remaining' coins into his pocket (really *all* of the coins go into the pocket, since he did not actually take any coin away from the original handful). Finally, the magician goes through the pantomime of making the single coin disappear. This trick is effectively a false transfer that depends both on the convincingness of the pantomime and also on the spectator not being able to count the original handful of coins. The Phantom Vanish Trick streamlines this idea by eliminating the handful of coins altogether. The magician simply pantomimes the actions of presenting an object and making it disappear. A real object is never presented at any point during the trick. Additionally, in the current experiment, the Phantom Vanish Trick was presented in the context of a silent video, meaning that the magician was not able to use false verbal information to mislead the spectators.

The Phantom Vanish Trick represents a novel contribution to the perception literature in that it has the potential to demonstrate that a spectator's top-down expectations can lead them to perceive illusory objects where none have been

presented. This is an extension of previous experiments that have shown that people may falsely infer the illusory motion of an object. For example, in the Vanishing Ball Illusion, spectators reported seeing an illusory ball leave the magician's hand. Similarly, Cui et al. (2011) reported that participants falsely perceived a coin being tossed by a magician from one hand to the other, despite the fact that the coin was actually retained in the initial hand that was making the toss.

Proponents of ecological theories of perception have made strong predictions about the potential for healthy adults to misperceive objects. Gibson (1979) asserted that it is impossible to induce the false visual perception of an object where none exists (barring optical illusions or pharmacological or psychiatric considerations). He states:

“Do we ever really “see” a nonexistent object or place as if it existed? I do not mean the virtual object in a mirror, or a pictured object behind the picture, or a mirage in the desert air, but a hallucinated object, a thing for which no invariants are present in the ambient light even when the presumably drugged or diseased observer walks around it. If it is true that the absence of all structure in the light specifies air, i.e., “nothing” in the sense of no thing, the answer must be that we do not and cannot (p. 223, original emphasis).”

While ecological theorists assert that human phenomenological experience is derived directly from bottom-up sensory information, inferential theorists (e.g., Helmholtz, 1867/1924; Gregory, 1997, 2009) propose that phenomenological experiences are derived from top-down interpretations of bottom-up sensory information. Thus, if participants do report the presence of objects after viewing the Phantom Vanish Trick, this would support an inferential theory of human visual perception. Such reports would imply that top-down information, in this case, the strong expectation that the object is present, is subjectively indistinguishable from veridical sensory information. In other words, participants will have the experience

of seeing an object even though it is not presented because they think that it ought to be there.

Based on informal observations of professional magic trick performances, as well as previous studies of sleight-of-hand magic tricks and pantomimes (e.g., Kuhn & Land, 2006; Phillips, Natter, & Egan, 2015), we predicted that some participants who watched the video of the Phantom Vanish Trick would report the presence of a nonexistent object, and that there were three possible outcomes. Of the participants who did experience the Phantom Vanish Illusion, some would indicate that they saw the magician make ‘something’ disappear while others would indicate that they saw the magician make a specific object disappear (e.g., a ‘silver coin’ or ‘red ball’). The third possible outcome was that some participants would fail to experience the Phantom Vanish Illusion, and they would simply provide a veridical report of the events shown in the video.

5.2 Methods for Online Experiment

5.2.1 Participants

Participants were recruited to take part in the study online (see Woods, Velasco, Levitan, Xan, & Spence, 2015 for a review of online behavioral research methods) through Amazon’s Mechanical Turk. There were 420 participants who completed the study (mean age = 33.5 years; age range = 19 – 73 years; male = 237), and an additional 23 participants who were excluded from the analysis because they did not complete the experiment. All participants self-reported as having normal or corrected-to-normal vision and no history of neurological illness or injury.

Participants were tested following a protocol approved by the University of Oxford Research Ethics Committee, and in accordance with the ethical standards laid down

in the 2008 Declaration of Helsinki. Each participant completed the experiment individually online and was given \$1.50USD as compensation for their time.

5.2.3 Stimuli and Procedure

The study was conducted online using Adobe Flash-based Xperiment software (www.xperiment.mobi). Participants completed the experiment using their own computers, and at the start of the study, participants had the option of viewing the stimuli in a discrete browser window or in ‘full-screen’ mode.

Stimuli consisted of a total of 22 videos. All videos were recorded in 1080 HD, at 30 FPS, using an iPhone 5s, and edited for length in iMovie. All of the videos were silent, to control for the fact that participants would be watching on their personal devices with varying audio capabilities. The stimuli set included one ‘practice’ video, and one ‘critical’ video – the Phantom Vanish Trick. There was only one version of each of these two videos, and they were shown to every participant. The other 20 videos included 15 ‘magic trick’ videos and 5 ‘non-magic control’ videos. There were three types of magic trick videos: Video 1- Miscellaneous Trick; Video 2- Vanish Trick; Video 4- Appearance Trick, and one type of control video: Video 3- Non-Magic Control. There were 20 videos because each of these four types of videos (Miscellaneous, Vanish, Appearance, and Non-Magic Control) was performed with five different objects: Condition 1- Silver Coin; Condition 2- Red Ball; Condition 3- Poker Chip; Condition 4- Silk Handkerchief, Condition 5- Crayon. See Table 5.1 for the number of participants in each of the five object conditions, and Figure 5.4 for an illustration of the five different object conditions.

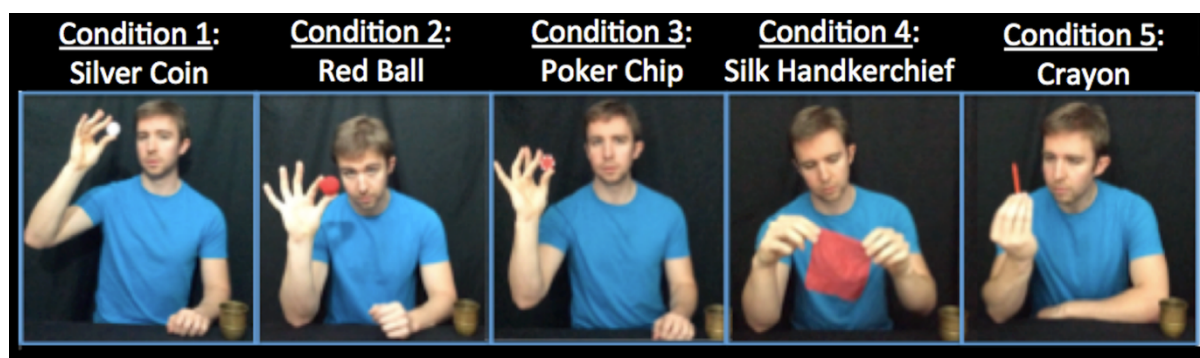


Figure 5.4. Five different objects were used in the five conditions of the experiment, and the objects varied for participants. Each participant saw four videos that always featured the same object before they watched the fifth video, the Phantom Vanish Trick.

Table 5.1.

Number of Participants in Each of Five Different Object Conditions

Condition	Object	Participants
1	Silver Dollar Coin	81
2	Red Ball	80
3	Poker Chip	100
4	Silk Handkerchief	79
5	Crayon	80

Participants watched a five-video sequence that was presented in an order designed to approximate a routine that might be performed within the context of a magic show. See Figure 5.6 for a breakdown of the five-video sequences that were possible with each of the five different object conditions. In all of the videos, a brass cup was visible on the table to the left of the magician. The cup was a receptacle for the objects. The first four videos in the sequence (which always showed an object) were intended to establish an expectation that the magician would take an object out of the cup, while the fifth video (which did not show an object) served as the critical video. See Figure 5.5 for an illustration of a five-video sequence.

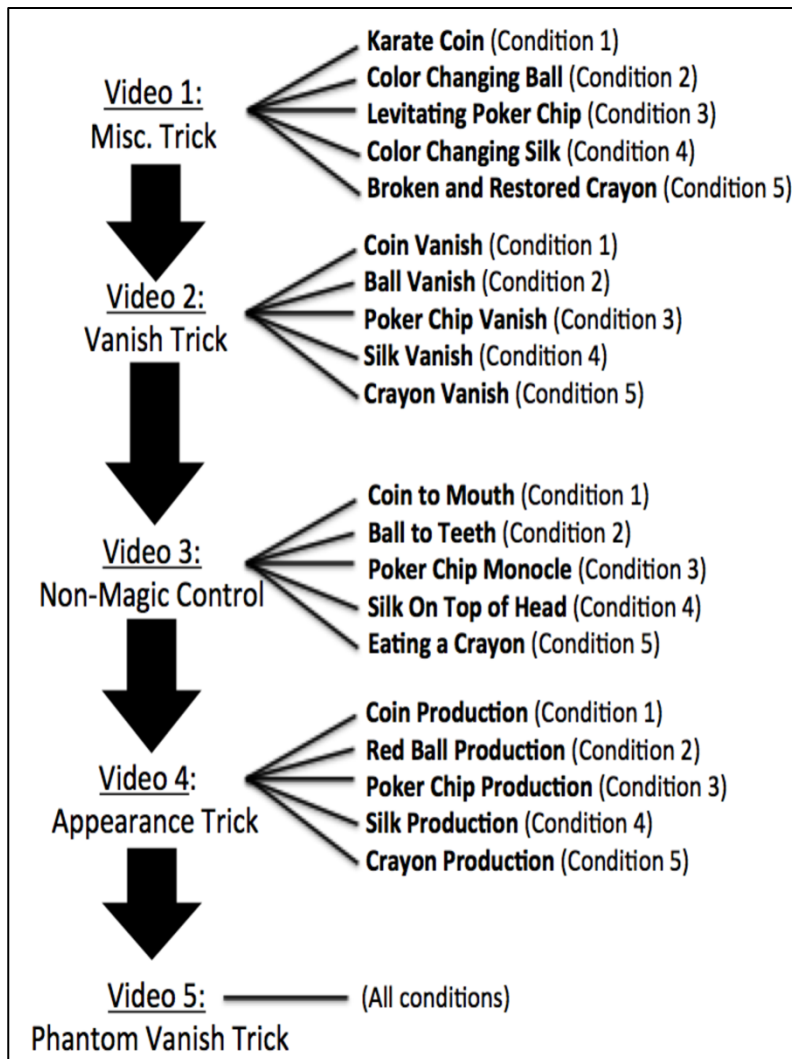
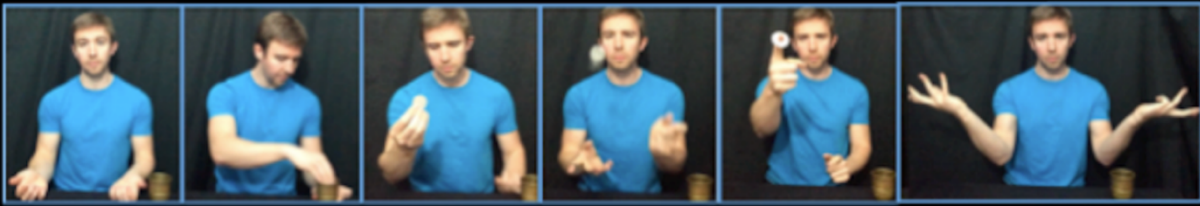
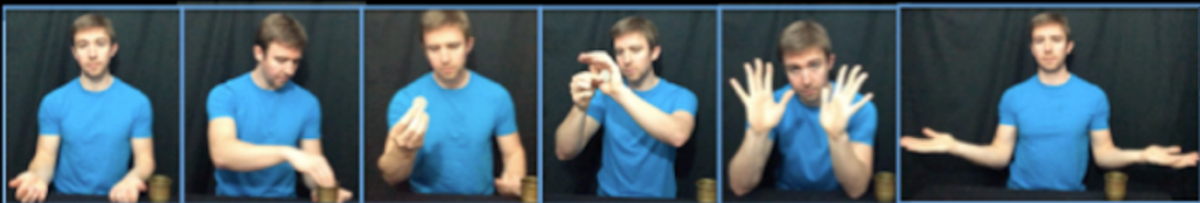


Figure 5.5. Each participant viewed one of five possible video sequences, and each sequence consisted of five videos: Video 1: Miscellaneous Trick; Video 2: Vanish Trick; Video 3: Non-Magic Control Video; Video 4: Appearance Trick; Video 5: Phantom Vanish Trick. The first four videos depicted a magician performing with a single object – either a silver coin (Condition 1), a red ball (Condition 2), a poker chip (Condition 3), a silk handkerchief (Condition 4), or a crayon (Condition 5); that is, the object varied for participants so that one group of participants watched a five-video sequence involving a silver coin while another watched a five-video sequence involving a red ball, etc.). The order of the tricks in the five videos that constituted a video sequence was intended to approximate a routine from a magic show.

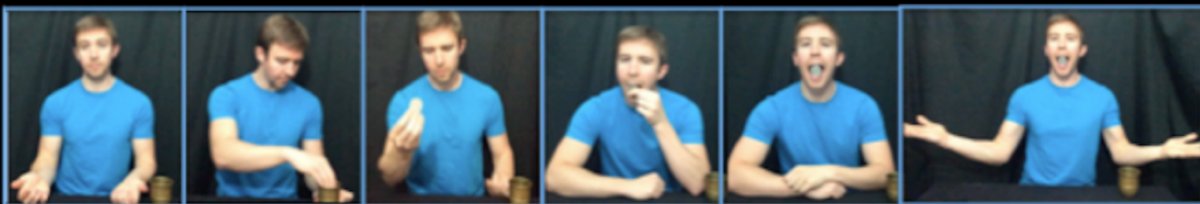
Video 1: Miscellaneous Trick (Karate Coin — magician puts his finger through a silver coin)



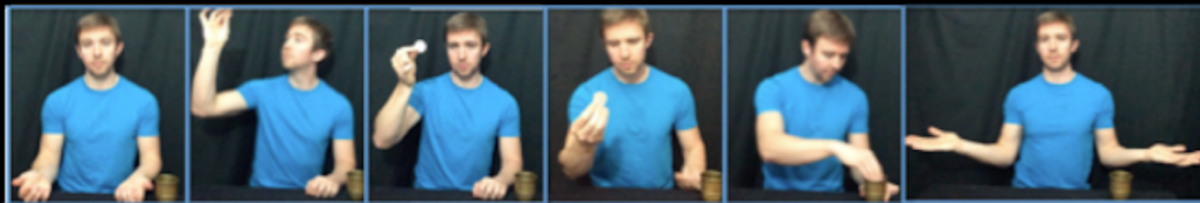
Video 2: Vanish Trick (Coin Vanish— magician makes a silver coin disappear)



Video 3: Non-Magic Control (Coin to Mouth — magician puts a silver coin in his mouth)



Video 4: Appearance Trick (Coin Production — magician produces a silver coin from air)



Video 5: Phantom Vanish Trick (magician pantomimes the action of making object vanish)

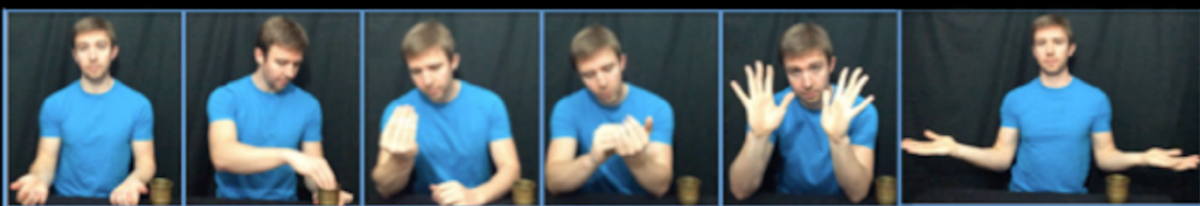


Figure 5.6. One of five possible video sequences viewed by a participant. All participants in Condition 1: Silver Coin, watched four videos featuring the magician performing with a silver coin before they watched a fifth video – the Phantom Vanish Trick, which did not include an object. Participants in Conditions 2 – 5 watched similar routines but featuring different objects, either a red ball, a poker chip, a silk handkerchief, or a crayon. Regardless of condition, the last video viewed was the same for each participant, and it was always the Phantom Vanish Trick.

Videos 1, 2, and 4 were presented as magic tricks. They were designed to establish that the magician was performing magical actions with the object. The tricks were presented so that the methods could not be easily inferred from the video, assuming that the participant did not have prior knowledge of the methods behind magic tricks. Video 1, the Miscellaneous Trick, showed the magician doing something magical with the object (e.g., breaking it and magically restoring it, or magically changing its color). Video 2, the Vanish Trick, showed the magician making the object seemingly disappear. Video 4, the Appearance Trick, showed the magician apparently producing the object from thin air.

Video 3, the Non-Magic Control, served as a manipulation check for demand characteristics. Participants had been informed that they would be watching a series of magic tricks, which might have led them to describe magic tricks even when the video did not depict a magic trick. Video 3 did not depict any apparent magical or impossible events (e.g., Video 3, Object Condition 1 depicted the magician placing the silver coin between his teeth). Therefore, if participants did report seeing magical or impossible events after watching this video, we would be unable to rule-out the influence of demand characteristics on participant responses to Video 5, the Phantom Vanish Trick.

Video 5, the Phantom Vanish Trick, served as the critical video of the experiment. Participants' responses to this video directly addressed our central question: Could a silent pantomime of a magic trick result in reports of objects where none were presented? This video showed the magician pantomiming the action of removing an object from the cup and then going through the motions of making the nonexistent object disappear. Unlike the first four videos, no object was shown in the Phantom Vanish Trick.

Participants were asked to write a description of each video (Question 1) and to provide three ratings of how surprising (Question 2), how impossible (Question 3), and how magical (Question 4) they found the video. At the end of the experiment, after watching all of the videos, participants were asked to report how interesting they generally considered magic tricks to be (Question 5). See Table 5.2, the *Spectators' Experience Questionnaire*, for the complete list of questions. The ratings for Q 2–4 were collected using a series of visual analog scales. Participants were presented with a continuous line anchored at one end with the words ‘not at all surprising’ (or impossible or magical) and at the other end with ‘very surprising’ (or impossible or magical). For each rating (of surprising, impossible or magical), participants were instructed: “Please use your mouse to indicate your response on the slider below” (see Reips & Funke, 2008 for a discussion of using computer-based visual analog scales).

Table 5.2.

Spectator's Experience Questionnaire

	<i>Response Format</i>	<i>Question</i>
1	<i>Written Verbal Response</i>	<i>Please describe what was shown in the video. Do your best to describe specific actions and events in the order that they occurred.</i>
2	<i>Visual Analog Scale (from ‘not at all surprising’ to ‘very surprising’)</i>	<i>How surprising did you find the events shown in this video?</i>
3	<i>Visual Analog Scale (from ‘not at all impossible’ to ‘very impossible’)</i>	<i>To what degree did the events shown in this video seem to be physically impossible?</i>
4	<i>Visual Analog Scale (from ‘not at all magical’ to ‘very magical’)</i>	<i>How magical did you find the events shown in this video?</i>
5*	<i>Visual Analog Scale (from ‘not at all interesting’ to ‘very interesting’)</i>	<i>In general, how interesting do you consider magic tricks to be?</i>

*Participants answered Q1–Q4 a total of five times, that is, once after each video in the five-video sequence, but they answered Q5 only once at the end of the experiment.

The critical question was Question 1 for Video 5 (Phantom Vanish Trick). The participants' responses to this question allowed us to determine whether they had experienced the Phantom Vanish Illusion. The ratings for Questions 2–4 for Video 5 were intended to corroborate the written reports (i.e., participants who experienced the Phantom Vanish Illusion should consider Video 5 to be more magical and/or impossible than those who did not experience the illusion). Throughout the experiment, the questions served to keep the participants actively engaged with the videos, and by asking the same questions about every video in the sequence, we avoided placing any special emphasis on Video 5 (Phantom Vanish Trick) that might have otherwise influenced the participants' responses.

In summary, the experiment began with the participants being informed, through onscreen written instructions, that they would be watching a series of short (less than 30 second) videos. They were told that they would be able to control when the videos started and that, during the experiment, each video could only be played once. Participants then completed the practice trial, and they were given the option to repeat the practice trial or to begin the experiment. The practice trial included a video, depicting the magician magically transforming one playing card into another, followed by Questions 1–4. Once participants confirmed that they wished to begin the trial, they were presented with a written cue: 'Press SPACE to start the trial'. Pressing the spacebar initiated the trial. The practice trial was in an identical format to the experimental trials; that is, after each video ended, participants were presented with Questions 1–4 of the Spectators' Experience Questionnaire (see Table 5.2). For each experimental trial, participants were required to answer each question (by typing text for Question 1 and by clicking on the visual analog scale slider for Questions 2–4) before they watch the next video in the sequence. This process was

repeated until participants had watched all five videos in the five-video sequence and responded to the four questions following each video. The *five* five-video sequences differed by the object that was used in Videos 1–4, but Video 5, the Phantom Vanish Trick, was the same for all participants regardless of which object condition they participated in. Finally, every participant answered one additional question (Question 5 of the Spectators’ Experience Questionnaire), “In general, how interesting do you consider magic tricks to be? Please use your mouse to indicate your response on the slider below”. Participants indicated their responses by clicking with their mouse at a point along a continuous line anchored at one end with the words ‘not at all interesting’ and at the other end with ‘very interesting.’

5.3 Pilot Experiment

Prior to running the full online experiment, I collected data from ten MTurk participants who completed a preliminary version of the online experiment. This version was identical to the one described in the previous section (Online Experiment Method), except that the presentation of the props were randomized (participants did not view the stimuli in the typical magician’s routine). In response to the “Participants description of [magic] tricks” question on the Phantom Vanish trials, five participants did not report an object, four participants reported seeing ‘something’ without specifying the object, and one participant reported having seen a coin.

5.4. Results of Online Experiment

5.4.1 Participants’ Written Reports for Question 1 on the Spectators’ Experience Questionnaire

Question 1 (Q1) of the Spectator’s Experience Questionnaire was presented immediately after each individual video of the five-video sequence, and the participants were asked:

“Please describe what was shown in the video. Do your best to describe specific actions and events in the order that they occurred.”

5.4.2 Participants’ Written Reports for the Magic Tricks (Videos 1, 2, and 4)

Videos 1, 2, and 4 were designed to be perceived as conventional magic tricks; each video depicted a trick that involved a single effect intended to create an apparent illusion of impossibility. As predicted, participants reported that they found the videos to be both impossible and magical. Overall, the videos were 97.3% effective in successfully conveying the intended magic tricks, and importantly, no participant reported the presence of a nonexistent object in Videos 1, 2, or 4. All 420 participants generated one written report for each of the four videos they viewed, for a total 1260 separate verbal reports. Only 34 reports, from 27 separate participants, indicated that the trick was perceived as non-magical:

- 21 reports related to Video 1, the Miscellaneous Trick – 4 participants reported the correct method behind the Karate Coin Trick, 1 participant reported the correct method behind the Color Changing Silk Trick, and 16 participants erroneously stated that they saw the magician ‘throw’ the chip upwards during the Levitating Poker Chip video (although this was not the genuine method, the trick was nevertheless perceived as non-magical);
- 9 reports related to Video 2, the Vanish Trick – 7 participants reported the correct method behind the Chip Vanish Trick, 1 participant reported the correct method behind the Silk Vanish Trick, and 1 participant reported the correct method behind the Crayon Vanish Trick;
- 4 reports related to Video 4, the Appearance Trick – 4 participants reported the correct method behind the Crayon Production.

5.4.3 Participants' Written Reports for the Non-Magic Control (Video 3)

Video 3, the Non-Magic Control video, was not a conventional magic trick in that it was not designed to create an illusion of impossibility; instead, the magician performed an action that was intended to appear surprising but not to violate any natural or physical laws. As predicted, none of the participants reported seeing anything impossible or magical in the Non-Magic Control video, and importantly, no participant reported the presence of a nonexistent object in Video 3. Some examples of the reports include: 'He took a coin out of the cup and put it between his teeth' or 'The man took the coin out of the cup and put it into his mouth. Then he waved his hands to the side, and rested his arms on the table afterward. Nothing magical happened.' The responses provided by the participants indicated that they were distinguishing between the magic trick videos (Videos 1, 2, and 4) and the Non-Magic Control (Video 3) because, unlike the reports for the magic trick videos, the participants did not report anything impossible or magical in response to Video 3.

5.4.4 Participants' Written Reports for The Phantom Vanish Trick (Video 5)

Video 5, the Phantom Vanish Trick, was the critical video of the experiment. In contrast to the first four videos, no object was visible in this video; the Phantom Vanish Trick was intended to induce the illusory perception of a 'phantom' object where no object was presented. Reports of phantom objects were categorized based on the participants' written reports for Q1:

(1) Participants who only described the veridical events of the video were categorized as not having reported experiencing the Phantom Vanish Illusion (e.g., 'The magician pretended to take something out of the cup and make it disappear' or 'His hands were empty. He reached into the cup. He then waved his hands around and then his hands remained empty');

(2) Participants who reported that the magician took ‘something’ out of the cup but did not provide any details about the object, were categorized as having reported experiencing the Phantom Vanish Illusion but *not* reporting a specific object (e.g., ‘He took something out of the cup and it disappeared’ or ‘The man takes the object from the cup into his hand. He makes a hand motion and it disappears. He points to his hand to show that it is indeed empty’);

(3) Participants who reported that the magician was performing with a specific object were categorized as having not only reported experiencing the Phantom Vanish Illusion but also having reported a specific object (e.g., ‘The magician removed a silver coin from the cup and placed it in his hand before making it disappear’).

In summary, of the 420 participants who responded to Q1 for Video 5, 284 participants (68%) were categorized as not having reported experiencing the Phantom Vanish Illusion (PVI) and 136 participants (32%) as having reported experiencing the PVI. Of the 136 participants categorized as having reported experiencing the PVI, 91 participants (21% of the total 420 participants) did not report a specific object and 45 participants (11% of the total 420 participants) reported a specific object. Of the 45 participants who reported specific objects, 39 (87%) reported seeing objects that were congruent with the objects they had been shown in the preceding videos. There were 6 exceptions, and all 6 participants reported seeing a coin (1 participant in Object Condition 2, Red Ball; 5 participants in Object Condition 4, Silk Handkerchief).

5.4.5. Participants' Ratings for Surprising (Question 2), Impossible (Question 3), and Magical (Question 4) on the Spectators' Experience Questionnaire

For every written report (Q1) collected for Videos 1–5, we also collected ratings from the participants for Surprising (Q2), Impossible (Q3), and Magical (Q4). See Table 5.2 for the questions administered to the participants. These ratings (Q2–4) were included in the experimental design to corroborate the written reports for Q1.

5.4.6. Participants' Ratings (Surprising, Impossible, and Magical) for the Magic Tricks (Videos 1, 2, and 4) Compared to the Non-Magic Control (Video 3)

For Videos 1–4, the written reports (Q1) suggested that participants considered the Non-Magic Control (Video 3) to be less Impossible and Magical than the magic trick videos (Videos 1, 2, and 4). We used a linear mixed-effects model to compare participants' ratings of Surprising (Q2), Impossible (Q3), and Magical (Q4) for the magic trick videos (Videos 1, 2, and 4) compared to the Non-Magic Control (Video 3). To fit the linear mixed-effects model, the error structure of the residuals need to be normal and heteroskedastic, satisfactory normality was achieved by applying a folded logarithmic transformation of the form: $\log((x + 1)/(101 - x))$ to the ratings data. We treated pairings of videos and ratings as fixed effects, such that each of the four videos (Videos 1, 2, 3, 4) was paired with each of the three ratings (Surprising, Impossible, Magical) for a total of 12 fixed effects. Participants were treated as random effects. Models were fitted using the nlme package (Pinheiro, Bates, DebRoy, Sarkar, & the R Development Core Team, 2016) in R (www.r-project.org). See Figure 5.7 for the participants' ratings of Surprising, Impossible, and Magical for Videos 1–4.

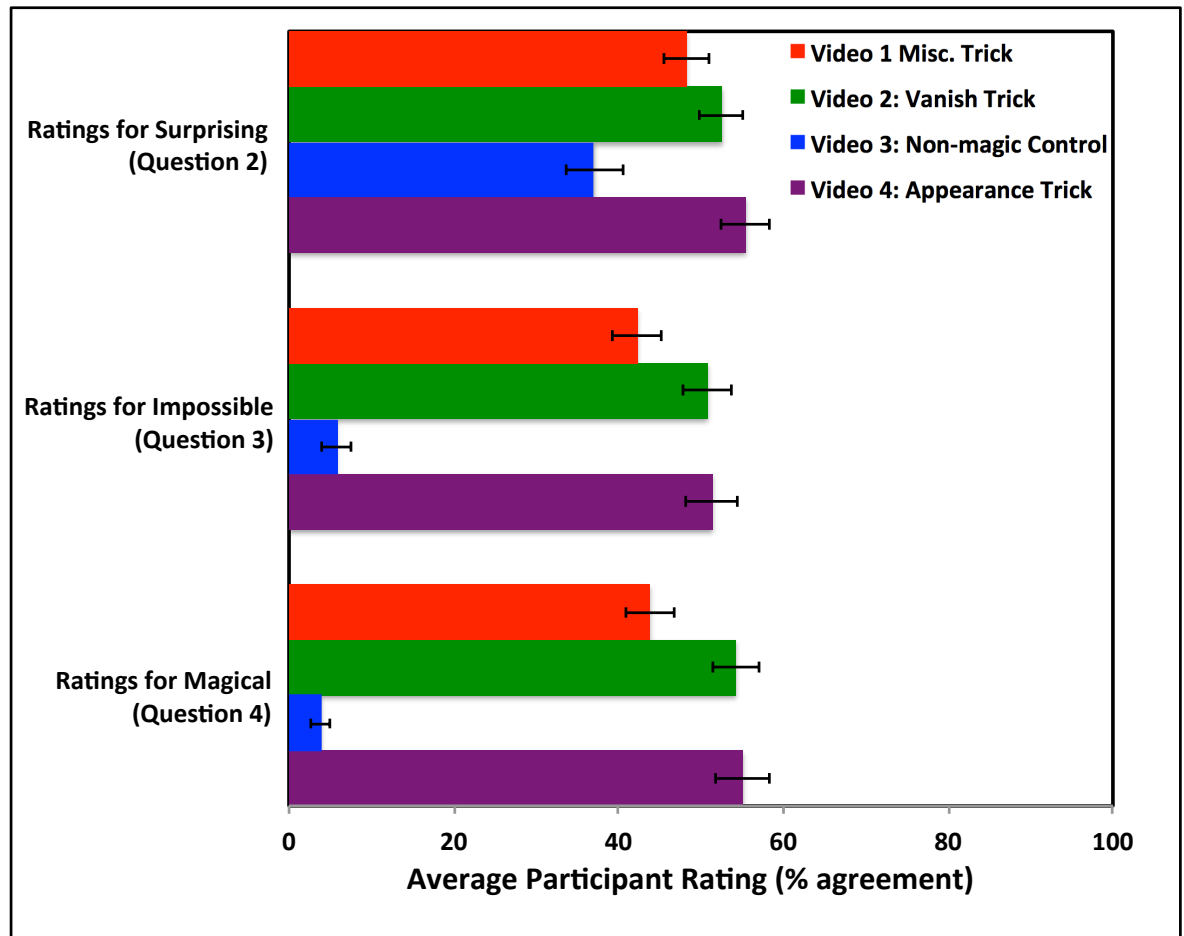


Figure 5.7. Average of the participants' ratings of surprising, impossible, and magical for Videos 1– 4. Error bars represent 95% Confidence intervals.

Participants' ratings for Surprising (Q2) were significantly lower for the Non-Magic Control Video 3 ($M=23.41$, 95% CI [19.95, 27.25]) than for each of the magic trick videos: Video 1 ($M=44.54$, 95% CI [39.65, 49.54]), $t(4609) = 8.23$, $p < 0.001$); Video 2 ($M=52.85$, 95% CI [46.84, 56.81]), $t(4609) = 11.09$, $p < 0.001$); Video 4 ($M=55.53$, 95% CI [50.53, 60.42]), $t(4609) = 12.02$, $p < 0.001$).

Participants' ratings for Impossible (Q3) were significantly lower for the Non-Magic Control Video 3 ($M= 1.35$, 95% CI [0.94, 1.85]) than for each of the magic trick videos: Video 1 ($M=34.66$, 95% CI [30.24, 39.34]), $t(4609) = 27.33$, $p < 0.001$);

Video 2 ($M=49.18$, 95% CI [44.18, 54.18]), $t(4609) = 32.48$, $p < 0.001$); Video 4 ($M=48.97$, 95% CI [43.98, 53.98]), $t(4609) = 32.41$, $p < 0.001$).

Participants' ratings for Magical (Q4) were significantly lower for the Non-Magic Control Video 3 ($M=0.99$, 95% CI [0.64, 1.41]) than for each of the magic trick videos: Video 1 ($M=36.80$, 95% CI [32.25, 41.59]), $t(4609) = 29.62$, $p < 0.001$); Video 2 ($M=54.47$, 95% CI [49.46, 59.39]), $t(4609) = 35.79$, $p < 0.001$); Video 4 ($M=55.10$, 95% CI [50.10, 60.00]), $t(4609) = 36.01$, $p < 0.001$).

In summary, the ratings (Q2–4) corroborated the written reports for Q1, indicating that participants considered the Non-Magic Control (Video 3) to be less Surprising, Impossible, and Magical than the magic trick videos (Videos 1, 2, and 4). These findings for ratings Q2–4 further support the earlier findings for Q1, and demonstrate that participants were clearly distinguishing between the magic trick videos (Videos 1, 2, and 4) and the Non-Magic Control (Video 3).

5.4.7 Participants' Ratings (Surprising, Impossible, and Magical) as Predicted by Participants' Written Reports for the Phantom Vanish Trick (Video 5)

Participants' written reports (Q1) for the Phantom Vanish Trick (Video 5) suggested that there were three different ways that participants responded to the PVI. We predicted that the Surprising (Q2), Impossible (Q3), and Magical (Q4) ratings from participants who were categorized as having reported experiencing the PVI (that is, participants who reported that they had seen an object apparently disappear during Video 5, see Figure 5.8) would be higher than the ratings from participants who were categorized as not having reported experiencing the PVI (that is, participants, whose experience could be described simply as watching the magician pantomime an action without an object). We also predicted that the ratings from participants who were categorized as having reported experiencing the PVI and

had also reported a specific object (e.g., a silver coin) would be higher than the ratings from participants who were categorized as having reported experiencing the PVI but had *not* reported a specific object (e.g., ‘the magician took something out of the cup’).

We calculated three linear regression models to predict ratings of Surprising, Impossible, and Magical (respectively) from the participants’ written reports for Q1 of the Phantom Vanish Trick. To fit the three simple linear regression models, the error structure of the residuals need to be normal and heteroskedastic, satisfactory normality was achieved by applying a folded reciprocal transformation of the form: $\log((x + 1)/(101 - x))$ to the ratings. For each model, our categorization of the participants’ reported experience of the PVI in Q1 for the Phantom Vanish Trick was used to predict the participants’ ratings of Surprising (Q2), Impossible (Q2), and Magical (Q2) for the Phantom Vanish Trick. Models were fitted using the lm package in R (www.r-project.org).

For each of the three models, we compared the simple regression model to a model that included four additional covariates. There were three categorical covariates: (1) participant gender (male or female); (2) computer screen-view setting (discrete or full-screen); (3) object used (i.e., Silver Coin, Red Ball, Poker Chip, Silk Handkerchief, or Crayon); and one continuous covariate: (4) participants’ self-reported interest in magic tricks (this covariate was transformed in the same way as the Surprising, Impossible, and Magical ratings, by applying a folded reciprocal transformation). The covariates were only included in the model reported if the likelihood test indicated that the covariates significantly improved the fit of the model. For example, none of the four covariates provided a significant improvement on the simple regression model for Impossible ratings, $F(7, 410) = 1.89, p = 0.07$ or

for Magical ratings, $F(7, 410) = 1.87, p = 0.07$, and therefore the simple regression models are presented for these two ratings. In contrast, for Surprising ratings, the likelihood test indicated that the inclusion of two covariates – object used and participants' self-reported interest in magic tricks – significantly improved the fit of the model, $F(8, 412) = 0.39, p < 0.01$, but that the inclusion of the two other covariates – participant gender and screen-view setting – did not improve the model, $F(2, 410) = 0.39, p = 0.68$.

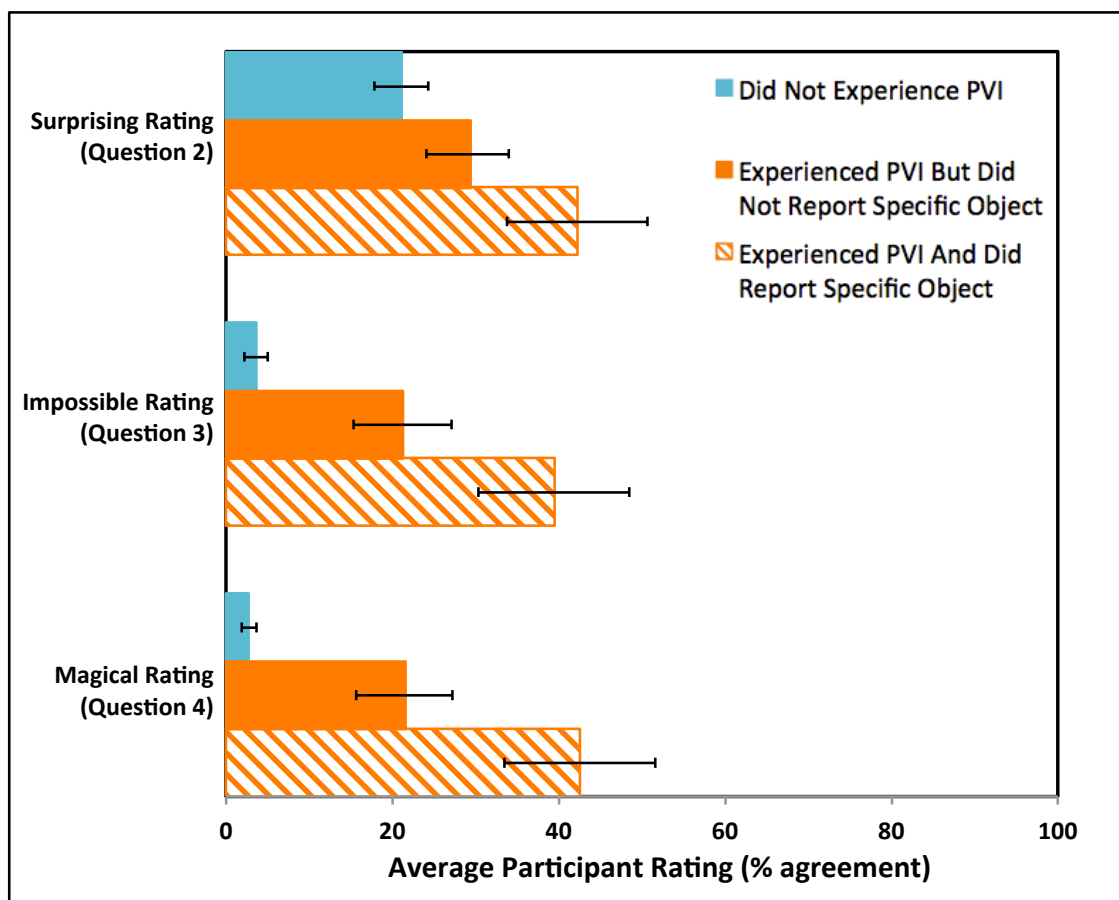


Figure 5.8. Average ratings of how surprising, impossible, and magical participants considered Video 5 (the Phantom Vanish Trick) comparing participants who did not report experiencing the Phantom Vanish Illusion (PVI) to those who did report experiencing the PVI. Error bars represent 95% Confidence intervals.

Surprising Ratings for Video 5, The Phantom Vanish Trick. In the first of three linear regression models, we found that participants' reported experience of the PVI (as categorized by their written responses to Q1 of Video 5) significantly predicted how Surprising they found the Phantom Vanish Trick (Q2, Video 5) while controlling for object used in the four videos that preceded the Phantom Vanish Trick (i.e., Silver Coin, Red Ball, Poker Chip, Silk Handkerchief, or Crayon) and the participants' self-reported interest in magic tricks, $R^2 = 0.11$, $F(7,412) = 7.59$, $p < 0.001$. There was a significant difference between the Surprising ratings of participants who did not experience the PVI ($M = 5.54$, 95% CI [3.18, 9.09]) and participants who did experience the PVI but did not report a specific object ($M = 12.44$, 95% CI [7.11, 20.45]), $t(417) = 3.29$, $p < 0.01$, as well as between participants who did not experience the PVI and participants who did experience the PVI and did report a specific object ($M = 27.24$, 95% CI [15.50, 43.03]), $t(417) = 5.35$, $p < 0.001$. In addition, for participants who did experience the PVI, there was a significant difference in the Surprising ratings between participants who did and did not report a specific object, $t(417) = 2.54$, $p = 0.02$. This analysis supports our prediction that the participants' written reports (Q1) for the Phantom Vanish Trick would be corroborated by their ratings of how Surprising (Q2) they found the Phantom Vanish Trick. Participants who we categorized (based on their written reports to Q1) as having reported experiencing the PVI rated the Phantom Vanish Trick as being more Surprising than those who we categorized as not having reported experiencing the PVI. Furthermore, participants who we categorized not only as having reported experiencing the PVI but also as having reported a specific object, rated the Phantom Vanish Trick as more Surprising than those who had not reported a specific object.

Impossible Ratings for Video 5, The Phantom Vanish Trick. In the second of three linear regression models, we found that participants' reported experience of the PVI (as categorized by their written responses to Q1 of Video 5) significantly predicted how Impossible they found the Phantom Vanish Trick (Q3, Video 5), $R^2 = 0.31$, $F(2,417) = 93.24$, $p < 0.001$. There was a significant difference between the Impossible ratings of participants who did not experience the PVI ($M = 0.98$, 95% CI [0.65, 1.36]) and participants who did experience the PVI but did not report a specific object ($M = 8.06$, 95% CI [5.73, 11.09]), $t(417) = 8.45$, $p < 0.001$, as well as between participants who did not experience the PVI and participants who did experience the PVI and did report a specific object ($M = 29.17$, 95% CI [20.38, 39.75]), $t(417) = 12.01$, $p < 0.001$. In addition, for participants who did experience the PVI, there was a significant difference in the Impossible ratings between participants who did and did not report a specific object, $t(417) = 5.10$, $p < 0.001$. This analysis supports our prediction that the participants' written reports (Q1) for the Phantom Vanish Trick are corroborated by their ratings of how Impossible (Q3) they found the Phantom Vanish Trick. Participants who we categorized (based on their written reports to Q1) as having reported experiencing the PVI rated the Phantom Vanish Trick as being more Impossible than those who we categorized as not having reported experiencing the PVI. Furthermore, participants who we categorized not only as having reported experiencing the PVI but also as having reported a specific object, rated the Phantom Vanish Trick as more Impossible than those who had not reported a specific object.

Magical Ratings for Video 5, The Phantom Vanish Trick. In the third of three linear regression models, we found that participants' reported experience of the PVI (as categorized by their written responses to Q1 of Video 5) significantly

predicted how Magical they found the Phantom Vanish Trick (Q4, Video 5), $R^2 = 0.37$, $F(2,417) = 127.5$, $p < 0.001$. There was a significant difference between the Magical ratings of participants who did not experience the PVI ($M = 0.89$, 95% CI [0.60, 1.22]) and participants who did experience the PVI but did not report a specific object ($M = 8.91$, 95% CI [6.56, 11.90]), $t(417) = 10.01$, $p < 0.001$, as well as between participants who did not experience the PVI and participants who did experience the PVI and did report a specific object ($M = 32.93$, 95% CI [24.09, 43.11]), $t(417) = 14.07$, $p < 0.001$. In addition, for participants who did experience the PVI, there was a significant difference in the Magical ratings between participants who did and did not report a specific object, $t(417) = 5.81$, $p < 0.001$. This analysis supports our prediction that the participants' written reports (Q1) for the Phantom Vanish Trick are corroborated by their ratings of how Magical (Q4) they found the Phantom Vanish Trick. Participants who we categorized (based on their written reports to Q1) as having reported experiencing the PVI rated the Phantom Vanish Trick as being more Magical than those who we categorized as not having reported experiencing the PVI. Furthermore, participants who we categorized not only as having reported experiencing the PVI but also as having reported a specific object, rated the Phantom Vanish Trick as more Magical than those who did not report a specific object.

5.5. Additional Control Experiments

In addition to the main online experiment just described, I also collected data for two additional versions of the experiment. The first of these experiments was an in lab version of the computer task in which participants completed an experiment that was identical to the online experiment except that they were tested individually using a computer and testing booth in Oxford's Department of Experimental

Psychology. The second experiment, also took place in Oxford's Department of Experimental Psychology, and participants were also tested individually, however instead of watching pre-recorded videos of magic tricks these participants each live performances of the tricks.

5.5.1 In-Lab Computer Experiment Methods

Participants 20 participants completed the study (mean age 23.1 years; male = 10.) All participants self-reported as having normal or corrected-to-normal vision and no history of neurological illness or injury. Participants were tested following a protocol approved by the University of Oxford Research Ethics Committee, and in accordance with the ethical standards laid down in the 2008 Declaration of Helsinki. Each participant was tested individually and given £5 as compensation for their time.

Procedure The procedure for the In-lab computer experiment was identical to the online experiment, except that participants did not complete the experiment on their own devices. All participants viewed the experiment on a CRT monitor (32.2 cm x 24.1 cm), operating at a refresh rate of 60 Hz and a spatial resolution of 1024 x 768 pixels. Monitor viewing distance was fixed at 50 cm, using a forehead and chin rest. Participants were randomly assigned to either 'Condition 1- Silver Coin' or 'Condition 2- Red Ball.'

5.5.2. In-Lab Computer Experiment Results

Of the 20 participants who responded to Q1 for Video 5, 10 participants (50%) were categorized as not having reported experiencing the Phantom Vanish Illusion (PVI) and 10 participants (50%) as having reported experiencing the PVI. Of the 10 participants categorized as having reported experiencing the PVI, 7 participants (85% of the total 20 participants) did not report a specific object and 3 participants

(15% of the total 20 participants) reported a specific object. Of the 3 participants who reported specific objects, all (87%) reported seeing objects that were congruent with the objects they had been shown in the preceding videos.

5.5.3. In-Lab Live Experiment Methods

Participants 10 participants completed the study (mean age 24.3 years, male = 3. All participants self-reported as having normal or corrected-to-normal vision and no history of neurological illness or injury. Participants were tested following a protocol approved by the University of Oxford Research Ethics Committee, and in accordance with the ethical standards laid down in the 2008 Declaration of Helsinki. Each participant was tested individually and given £5 as compensation for their time.

Procedure The procedure for the In-lab live experiment was identical to the online experiment, except that participants did not complete the experiment on their own devices. Except that instead of watching the recorded videos, participants were seated at a table, approximately 1 meter away from the magician, who performed the tricks live. Participants completed the Practice Trial, and the Spectators Experience Questionnaire on a lap top computer. All 10 participants were assigned to ‘Condition 1- Silver Coin.’

5.5.4. In-Lab Live Results

Of the 10 participants who responded to Q1 for Video 5, 6 participants (60%) were categorized as not having reported experiencing the Phantom Vanish Illusion (PVI) and 4 participants (40%) as having reported experiencing the PVI. Of the 4 participants categorized as having reported experiencing the PVI, 3 participants (30% of the total 10 participants) did not report a specific object and 1 participant (10% of the total 10 participants) reported a specific object, a coin.

5.6. Discussion

Our experiment investigated the illusory presence of objects in scenes where no object was presented. The Phantom Vanish Illusion demonstrates that spectators' expectations, in response to magic tricks, can lead them to imagine the existence of an object that 'ought to be there.' In some cases, this imagined representation was vivid enough to be mistaken for a veridical visual perception. Thus, this experiment extends previous research demonstrating that magicians' misdirection techniques can induce misperceptions of visual experiences.

One third of our participants reported having been shown an object after watching a video where no object was presented. Our Phantom Vanish Illusion paradigm is the first investigation of sleight-of-hand magic tricks that has involved participants spontaneously reporting their illusory experiences. After watching each video, participants provided written reports describing what they had been shown. In addition to collecting written reports, we asked the participants to rate how surprising, impossible, and magical they considered the videos. These ratings served to corroborate the written reports: participants who reported phantom objects rated the Phantom Vanish Trick video to be more surprising, impossible, and magical than those who did not experience the illusion. Past research, on false transfer tricks (e.g., Beth & Ekroll, 2015; Cui et al., 2011) and on the Vanishing Ball Illusion (e.g., Triplett, 1900; Kuhn & Land, 2006; Thomas & Didierjean, 2016), has involved misleading participants about the motion and location of an object: the object was shown, and then was apparently passed from one hand to the other while secretly being retained in the first hand; or, the object was shown and then apparently tossed into the air while being secretly retained in the hand (or secretly dropped into the magician's lap). In contrast, the Phantom Vanish Illusion paradigm entirely eliminates the need to present an object during the critical video. Overall, our paradigm provides strong

evidence that participants who were categorized as having experienced the illusion were honestly confusing ‘phantom’ objects for genuine objects. Our results also suggest that the participants’ reports of ‘phantom’ objects cannot be attributed to demand characteristics. Participants’ responses to the Spectators’ Experience Questionnaire for Video 3 (the Non-Magic Control video) indicated that the participants were not simply describing every video they watched as being impossible or magical merely because they had been told that they would be watching magic tricks. No participant reported seeing anything impossible or magical after watching Video 3, which was rated as significantly less impossible and less magical than the magic trick videos (Videos 1, 2, and 4). These results also raise intriguing questions about exactly what makes-up these ‘phantom’ objects, and what these reports reveal about human perception.

One might argue that the participants’ reports of illusory objects can be attributed to memory errors rather than perceptual errors. In other words, participants who reported seeing the phantom objects may not have had a phenomenological experience of ‘seeing’ the object during the Phantom Vanish Trick video, instead they may have retrospectively confabulated the object after they had been cued to describe the events in the video. The design of our experiment allows us to exclude two memory-related factors that might otherwise have contributed to the illusion: post-event misinformation (including verbal and non-verbal information) and false verbal suggestions.

There is a rich literature on misinformation and the unreliability of eye-witness testimony. Researchers have repeatedly demonstrated that people are capable of confusing imaginary events with real memories (see Loftus, 2005 for a review). The idea that people can be led to report imaginary events has been

established by research on the effects of leading questions. Loftus and Palmer (1974) showed that participants could be induced to remember seeing things that were not presented in response to leading questions. One week after having watched a video of a car accident, participants were explicitly asked ‘Did you see any broken glass?’ The reported false memories of broken glass could not have been derived directly from the video, because the video did not actually show any broken glass; thus, the false memory was arguably induced by the question itself. Other researchers have demonstrated that false verbal suggestions presented *co-currently* with events can also induce false reports (Wiseman, Greening, & Smith, 2003; Wiseman & Greening, 2005; Wilson & French, 2013).

Similar results have been obtained in the absence of verbal misinformation, such as when Gurney, Pine, and Wiseman (2013) demonstrated that participants who were being questioned about a video recording of a robbery could be induced to report false information in response to non-verbal ‘leading gestures’. For example, when the interviewer stroked his chin, while asking participants if they noticed any distinguishing features on the robber in the video, participants were more likely to falsely report that the robber had a beard compared to participants who were asked the question without the accompanying gesture.

In both our Phantom Vanish Illusion paradigm, and previous research with the Vanishing Ball Illusion paradigm, the silent video clips that serve as stimuli preclude the use of false verbal suggestions during stimulus presentation. The Vanishing Ball Illusion paradigm involves asking participants a series of questions relating to the ball. After watching the video of the trick, the participants were asked to mark the location of the last place they saw the ball on a still picture that depicted the magician. Participants were considered to be sensitive to the illusion if they

indicated that they had seen the ball leave the magician's hand on the last throw. They were considered insensitive to the illusion if they (correctly) marked the magician's hand as being the last place where they had seen the ball. Participants were then asked to describe what they saw, asked how the illusion was created, and given a yes/no forced choice question: "Did you see the ball move up on the final throw?" (Kuhn & Land, 2006). In contrast, in our Phantom Vanish Illusion paradigm, the participants freely reported seeing the phantom object in response to a question that asked them to recall 'actions' and 'events' but made no specific reference to an object. In the Phantom Vanish Illusion paradigm, given that there was no object presented during the Phantom Vanish Trick video, care was taken to ask participants non-leading questions, so as to rule-out the potential for post-event information to generate introspective errors during the participants' recollection of the events. The omission of a direct question about the object in the Phantom Vanish Illusion paradigm may partially account for the fact that 68% of our 420 participants did not report experiencing the Phantom Vanish Illusion.

With regards to ecological versus inferential theories of perception, our results do not support Gibson's (1979) specific ecological prediction that healthy sober people can never 'see' a nonexistent object – 32% of the 420 participants who completed our experiment reported that they had been shown objects when none had been presented. These results support a more inferential model of human perception. This concept, that conscious phenomenological experience is actively constructed by combining top-down cognitive processes with bottom-up sensory information, may offer insight into how participants came to experience the Phantom Vanish Illusion.

Gregory's (2009) framework for classifying illusory phenomenon includes both paradoxical illusions (e.g. Figure 5.8) and fictional illusions (e.g. Figure 5.9, above). Paradoxical illusions refer to perceptions that seem to be logically impossible (e.g., Kulpa, 1987), while fictional illusions refer to perceptual experiences that fail to directly correspond with sensory information (e.g., modal and amodal completions). Fictional illusions do not necessarily need to be based on false assumptions. For example, the amodal completion of objects is often based on accurate inferences: if one were to see a person standing behind a picket fence, and this caused the image of the person to be partially occluded, it would normally be correct to assume that the person's body really extends to areas occluded by the fence, rather than them being neatly sliced into separate sections.

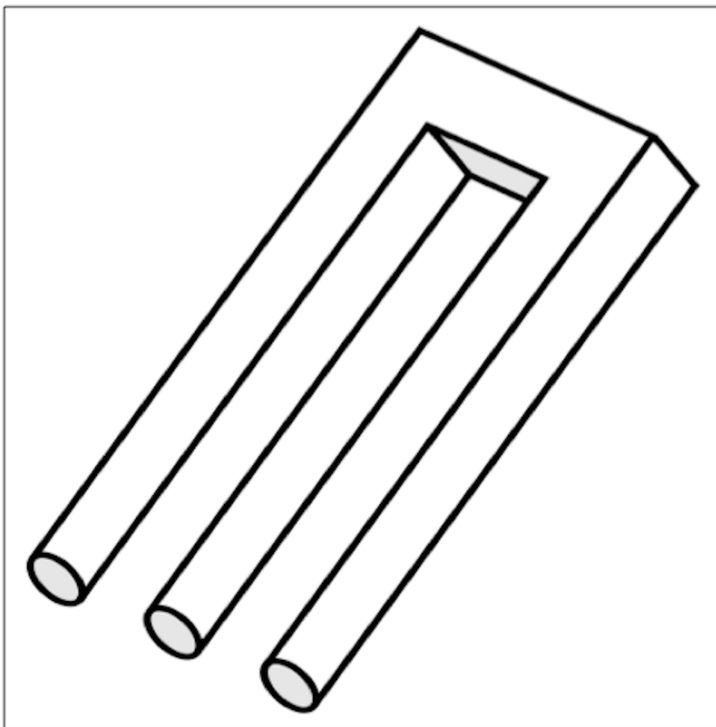


Figure 5.9. A 'Devil's Fork'. This is an example of a paradox illusion. People can easily perceive the individual parts of the figure, but the whole image creates an experience of an 'impossible object' (e.g., Kulpa, 1987)

I propose that sleight-of-hand illusions be classified as 'paradoxical fictions'. Magic tricks are designed to exploit spectators' inferences, along with their intuitions about their own perceptual systems, to create the 'illusion of impossibility' (e.g., Nelms, 1969; Oritz, 2006). Magic tricks are paradoxical in that an effective magic

trick will appear to violate the laws of nature. For example, in a ‘vanishing’ trick, an object appears to pass from existence into nonexistence. Magic tricks are fictional in that the spectators’ perceptual experiences can often differ dramatically from bottom-up sensory information, as in the case with our Phantom Vanish Illusion or with the Vanishing Ball Illusion. These magical experiences can be considered “failures of visual metacognition” (Beth & Ekroll, 2015, p. 520). That is to say, we tend to believe what we see, and we are generally unaware of the discrepancy between how our perceptual system actually works and how we think it ought to work. Magic effects result from ‘hacking’ otherwise adaptive perceptual processes to create false fictional experiences that lead to paradoxical experiences. In the case of the Phantom Vanish Illusion, people would generally not believe that they could ‘see’ an object where one does not exist. The ‘illusion of impossibility’ occurs when the magician reveals the conflict between reality and the spectators’ perceptual experience. At the ‘climax’ of the Phantom Vanish Trick, the magician clearly shows that both of his hands are empty. Because the spectator does not believe that they could have misperceived an object that was never really there, they are unable to intuit that the true method is even possible.

One explanation for why participants reported phantom objects during the Phantom Vanish Trick is that the participants’ top-down expectations about the object outweighed the bottom-up sensory counter-evidence (the absence of the object) (Kuhn & Rensink, 2016). Various top-down expectations may have contributed to the creation of an amodal spatiotemporal representation of the object (Beth & Ekroll, 2015; Thomas & Didierjean, in press). Among the 136 participants who were categorized as having experienced the Phantom Vanish Illusion, those who reported a specific object (e.g., a coin) might have based their reports on the

perceptual experience of modal completion (they had the impression that an object had been openly displayed), while those who reported an object but did not specify which object, might have based their reports on an amodal completion (they had the impression that an object was presented, but that it was occluded by the magician's hand). However, one limitation of our written response format for Question 1, in which participants freely reported their experiences, is that we cannot determine whether the participants who did not report a specific object might have been capable of naming a specific object, if asked. In any case, all participants who reported having seen a phantom object apparently committed a metacognitive error of failing to distinguish the representation from a real object.

Participants' top-down expectations may have been influenced by multiple factors. Because there is no object presented during the critical video, the Phantom Vanish Illusion paradigm can potentially be used to isolate a variety of variables that may contribute to sleight-of-hand illusions, including perceptual priming (i.e., the expectations established by the preceding videos¹⁶), social cues (i.e., the gaze and head direction of the magician), and the convincingness of the magician's pantomime (i.e., the grasp of the non-existent object). In future studies, each of these factors could be manipulated to isolate their respective roles in creating the Phantom Vanish Illusion. The preceding four videos in the five-video sequence did include real objects. These videos may have served as perceptual primes, analogous to the real

¹⁶ Of interest here is the fact that six participants in our experiment did *not* actually report seeing a phantom object that was congruent with the object they had been shown in previous videos. This might be attributable to the fact that the magician depicted in the videos predominately practices and performs sleight-of-hand magic with coins, meaning that his pantomimed grasp shown during Video 5 (Phantom Vanish Trick) may have been most closely related to the grasp that would be used to hold a coin. Alternatively, participants might have had a prior expectation established outside the experiment, that magic performances often involve disappearing coins.

tosses that precede the false throw in the Vanishing Ball Illusion. One experiment (Kuhn & Rensink, 2016) has shown that manipulating the perceptual priming aspect of a magic trick (the veridical throws that precede the false throw in the Vanishing Ball Illusion paradigm) affects the probability that participants will experience the illusion, and that the illusion can still be effective when the perceptual primes are eliminated entirely from the trick (i.e., the magician simply showed the ball and then immediately performed the fake toss without making any veridical throws). This suggests that our Phantom Vanish Illusion might still be effective for some participants, even if the experiment were modified to reduce or even eliminate the preceding videos. For example, one could manipulate which objects are shown in the preceding videos or manipulate the number of videos that precede the Phantom Vanish Trick. Additionally, the social cues of the magician could be manipulated by occluding the magician's face, or by including a condition where the magician maintains a fixed, unmoving gaze (see Thomas & Didierjean, 2016).

In summary, the Phantom Vanish Illusion represents a new contribution to the rapidly growing field of the 'Science of Magic' – the use of methodologies inspired by performance magic to experimentally investigate human psychology. Just as optical illusions and visual arts represent a resource for visual scientists, the more elaborate illusions created by magic performances can be used to examine more complex elements of human visual cognition. I hope that the Phantom Vanish Illusion paradigm represents not only a novel contribution to the Science of Magic, but more generally, a new tool for perception researchers looking to untangle the complex influences of top-down factors on the way people process dynamic visual scenes.

Finally, on the topic of using the Phantom Vanish Paradigm as a flexible tool for subsequent research, the following section details a preliminary investigation in which I adapted the Phantom Vanish Paradigm to investigate the role of explicit misinformation in distorting participants reports of a dynamic visual scene.

5.7. Explicit misinformation and the Phantom Vanish Magic Trick

“It was quite simple. All that was needed was an unending series of victories over your own memory. “Reality control,” they called it...”

George Orwell’s 1984

5.7.1. Introduction: Perception and alternative facts

We live in interesting times. Questions of truth, perception, deception, and misdirection are increasingly relevant to contemporary policy discussions. The following experiment was directly inspired by the concept of ‘alternative facts’ that was raised by the Counselor to the (U.S.) President, Kellyanne Conway, on January 22, 2017 (Sunderland, 2017). Conway was referring to a White House Press Briefing delivered by Sean Spicer, who had asserted that the crowd that had gathered in Washington D.C. to witness the inauguration of Donald J Trump, marked “the largest audience to ever witness an inauguration – period- both in person and around the globe.” He went on to claim that 420,000 people had ridden the D.C. metro that day. These assertions were contradicted by available evidence including aerial photographs and the available ridership data from the Washington Metropolitan Area Transit Authority. Following this press briefing, Ms. Conway was subsequently confronted by NBC reporter Chuck Todd, who questioned her about the apparent inconsistency, which he explicitly referred to as a “provable falsehood.” In response to this question, she responded: “Our press secretary, Sean Spicer, gave *alternative facts*” (emphasis added). The Trump White House has refused to

relinquish this demonstrably false narrative, and as of December 7, 2017, Donald Trump himself averaged 2.9 false claims per day in office (Dale, 2017). Such a climate raises an interesting empirical question as to how explicit misinformation might influence people's perceptions of reality.

The concept of alternative facts is arguably analogous to the misdirection techniques practiced by magicians, and some of the earliest empirical investigations of misinformation and testimony can be traced to investigations involving magic tricks. For example, Hodgeson and Davey (1887), systematically documented the errors of testimony of witnesses to staged pseudo-séances. More recently, I had used the Phantom Vanish Magic Trick Paradigm (see chapter 5; Tompkins, Woods, & Aimola-Davies, 2016) to demonstrate that viewers reported misperceptions of non-existent 'phantom' objects after they had watched short video clips and even live performances of sleight-of-hand magic tricks. In the original experiment, participants viewed five separate silent videos of magic tricks. The videos depicted the magician performing apparently impossible actions with small objects, either a coin, a red ball, a poker chip, a handkerchief, or a crayon. Each video showed one ostensibly impossible event, e.g., the object might vanish, or it might appear from nowhere, or it might be broken and magically restored. Each participant watched a total of 5 videos, and on the fifth video, no object was actually presented— the magician, using his empty hands, simply pantomimed the actions of presenting an object and making that object vanish (see Figure 5.10). Despite the absence of the object, 32% of participants who viewed the 'trick' reported having seen the magician present an object. These results were particularly novel because the participants' reports of phantom objects could not be attributed to any form of explicit misinformation, and they occurred in the complete absence of the misperceived

object (i.e. the illusion related to the *presence* of an object rather than the *motion* of an object in the scene). Elements that could have led to the phantom vanish illusion in the original experiment included the pantomimic actions of the magician and the perceptual priming that resulted from viewing the videos leading up to the Phantom Vanish Trick.

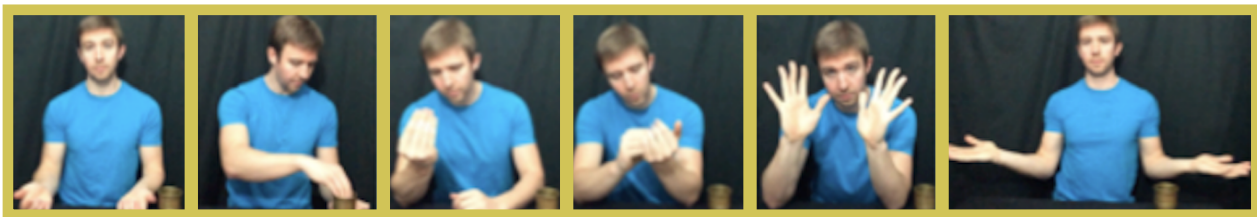


Figure 5.10. A visual depiction of the Phantom Vanish Trick. In the course of the 19 second video, the magician showed both hands to be apparently empty, reached into a cup on the table, and pantomimed the actions of removing an object from the cup and making it disappear. No object was ever really present.

The purpose of the following experiment was two-fold: first, to investigate how participants might experience the Phantom Vanish Illusion in the absence of a perceptual prime and second, to investigate the influence of misinformation exposure.

To address these questions, I developed a streamlined version of the original Phantom Vanish experiment. Instead of watching five videos, participants were only shown a single video: The Phantom Vanish Magic Trick. Thus, in addition to not being shown an object being taken from the cup during the critical video, participants *never* saw an object during the entire experiment. Furthermore, the experiment instructions were modified so as to expose participants to varying amounts of written misinformation about the video they watched.

I predicted that reports of the Phantom Vanish Illusion (PVI) would be modulated by exposure to misinformation- with participants who were not exposed to misinformation being less likely to report experiencing the PVI compared to participants who were exposed to misinformation. Furthermore, I predicted that participants who were exposed to repeated instances of misinformation would be more likely to report experiencing the PVI than those participants who were exposed to misinformation only once.

These predications were derived from previous experiments on the perception of magic tricks as well as the effects of misinformation on memory. In the original Vanishing Ball Illusion, reported by Kuhn and Land (2006), the magician would present a ball and clearly toss the ball into the air and catch it two times; the magician would then appear to make a third toss, but, in reality, he would retain the ball in his hand. Participants were said to have experienced the Vanishing Ball Illusion if they reported ‘seeing’ the ball leave the magicians hand on the third false toss. The first two real tosses arguably served as ‘perceptual primes’ conditioning the viewers to think that the magician was simply tossing the ball into the air and catching it, thus increasing the power of the illusion that a ball had left the magicians hand on the third false toss. Kuhn and Rensink (2016) adapted this original paradigm and varied the number of ‘real’ throws that the participants saw before they watched the fake throw. Their results showed that some participants would still report ‘seeing’ an illusory ball, even when the magician had not been shown to have made real tosses before his third false toss. Furthermore, researchers studying memory and misinformation have demonstrated that exposure to misinformation can lead to participants confusing imagined fictional events with true memories (see Loftus, 2005 for review), particularly in the context of magic performances (Wiseman & Greening, 2005).

5.7.2. Method

Participants

125 neurologically healthy participants with normal or corrected-to-normal-vision (mean age = 33.2 years; age range 18 – 67; male = 72) were recruited via Prolific Academic. All participants self-reported as having normal or corrected-to-normal vision and no history of neurological illness or injury. Participants were tested following a protocol approved by the University of Oxford Research Ethics Committee, and in accordance with the ethical standards laid down in the 2008 Declaration of Helsinki. Each participant completed the experiment individually online and was given £0.80 GBP as compensation for their time.

Stimuli and Procedure

The study was conducted online using Adobe Flash-based Xperiment software (www.xperiment.mobi). Participants completed the experiment using their own computers. The procedure was based on the Phantom Vanish Experiment (see part 1 of this chapter), except instead of watching a practice video followed by a series of five videos, participants only viewed a single video— the Phantom Vanish Trick. Additionally, the written instructions that accompanied the video varied between participants (see Table 5.3 for details of the instruction manipulations). The instructions were manipulated across four different experimental conditions:

- Condition 1: Participants were exposed to *no misinformation*
- Condition 2: Participants were exposed to *pre-event misinformation*
- Condition 3: Participants were exposed to *post-event misinformation*
- Condition 4: Participants were exposed to *both pre- and post-event misinformation*.

The experiment began with the participants being informed, through onscreen written instructions, that they would be watching a short (less than 30 second) video (see Appendix H for full instruction sets). Participants in conditions 1 and 3 were

simply informed that they would be watching ‘a short video,’ while participants in conditions 2 and 4 were told that they would be watching a ‘a short video of a coin trick.’ All participants were told that they would be able to control when the video started and that, during the experiment, the video could only be played once.

All participants watched the same video, the Phantom Vanish Trick. The video lasted 19 seconds and showed the magician pantomiming the action of removing an object from a cup and then going through the motions of making the nonexistent object disappear. The magician’s hands were actually empty during the entire video and no object was ever shown.

After the video ended, participants were asked to write a description of what they had seen (Question 1). The wording of this question varied between conditions. Participants in conditions 1 and 3 were asked to ‘*Please describe what was shown in the video*’ while participants in conditions 2 and 4 were asked to ‘*Please describe the coin trick that was shown in the video.*’ All participants were then asked to provide three ratings of how surprising (Question 2), how impossible (Question 3), and how magical (Question 4) they found the video. The ratings for Q 2–4 were collected using a series of visual analog scales. Participants were presented with a continuous line anchored at one end with the words ‘not at all surprising’ (or impossible or magical) and at the other end with ‘very surprising’ (or impossible or magical). For each rating, participants were instructed: “Please use your mouse to indicate your response on the slider below” (see Reips & Funke, 2008 for a discussion of using computer-based visual analog scales. See Appendix F for a reproduction of the scales).

Table 5.3.
Misinformation Instruction Manipulations Between Conditions

Manipulation	Conditions	Instruction wording*
No pre-event misinformation	1 & 3	<i>For this experiment you will be asked to watch a short video</i>
Pre-event Misinformation	2 & 4	<i>For this experiment you will be asked to watch a short video of a coin trick</i>
No post-event misinformation	1 & 2	<i>Please describe what was shown in the video. Do your best to describe specific actions and events in the order that they occurred.</i>
Post-event misinformation	3 & 4	<i>Please describe the coin trick that was shown in the video. Do your best to describe specific actions and events in the order that they occurred.</i>

* Manipulated text is **presented in bold**

5.7.3. Results

Participants' Written Reports for the Phantom Vanish Trick

All participants viewed the same video clip of the Phantom Vanish Trick and generated a written report of their experiences. The Phantom Vanish Trick was intended to induce the illusory perception of a “phantom” object where no object was presented. I categorized reports of phantom objects based on the participants' written reports for Q1:

- (1) Participants who only described the veridical events of the video were categorized as not having reported experiencing the PVI (e.g., “The magician pretended to take something out of the cup and make it disappear” or “His hands were empty. He reached into the cup. He then waved his hands around and then his hands remained empty”);
- (2) Participants who reported that the magician took “something” out of the cup but did not provide any details about the object, were categorized as having reported experiencing the PVI but *not* reporting a specific object (e.g., “He took something out of the cup and it disappeared” or “The man takes the object from the cup into his hand. He makes a hand motion and it disappears. He points to his hand to show that it is indeed empty”);
- (3) Participants who reported that the magician was performing with a specific (phantom) object were categorized as having not only reported experiencing the PVI, but also having reported a specific object (e.g., “The magician removed a silver coin from the cup and placed it in his hand before making it disappear”).

In summary (see also Table 5.4, of the 125 participants across all conditions who responded to Q1, 73 participants (58%) were categorized as not having reported experiencing the PVI and 52 participants (42%) as having reported experiencing the PVI. Of the 52 participants categorized as having reported experiencing the PVI, 34 participants (27% of the total 125 participants) reported a specific object. Of the 34 participants who reported specific objects, 32 (86% of those who reported objects) reported seeing a coin; the other two participants reported seeing a small ball¹⁷.

Table 5.4.

Participants who Experienced the Phantom Vanish Illusion (PVI), and Participants who Reported Phantom Objects

Condition (Misinfo Exposure)	Total N	Experienced PVI N (Percent)	Phantom Object Reports N (Percent)
1 (No Misinfo)	35	10 (29%)	2 (6%)
2 (Pre-Misinfo)	30	11 (37%)	6 (20%)
3 (Post-Misinfo)	30	15 (50%)	12 (40%)
4 (Pre & Post Misinfo)	30	16 (53%)	14 (47%)

Note. Participants who specifically reported an object are included in both the ‘Experienced PVI’ and the ‘Phantom Object Reports’ columns.

¹⁷ The fact that 2 participants reported seeing a ball was somewhat unexpected, given that participants in the original paradigm (chapter 5) were most likely to report seeing a coin, and I had previously hypothesized that this was due to positioning of the ‘grip’ of the magician’s hand during the pantomime. One possibility that might explain these reports of a ball might be that those participants were familiar with the classic ‘cups and balls’ trick, one of oldest documented magic tricks that is still relatively popular today. Previous exposure to the cups and balls trick might have influenced participants’ responses, although given the extremely small *n*, combined with the inherent limitations of this paradigm, this is pure speculation.

Participants' Ratings (Surprising, Impossible, and Magical) as Predicted by Participants' Written Reports for the Phantom Vanish Trick (Video 5)

I predicted that the Surprising (Q2), Impossible (Q3), and Magical (Q4) ratings from participants who were categorized as having reported experiencing the PVI (that is, participants who reported that they had seen an object apparently disappear during Video 5, see Figure 5.11) would be higher than the ratings from participants who were categorized as not having reported experiencing the PVI (that is, participants, whose experience could be described simply as watching the magician pantomime an action without an object). I also predicted that the ratings from participants who were categorized as having reported experiencing the PVI and had also reported a specific object (e.g., a silver coin) would be higher than the ratings from participants who were categorized as having reported experiencing the PVI but had *not* reported a specific object (e.g., 'the magician took something out of the cup').

I calculated three linear regression models to predict ratings of Surprising, Impossible, and Magical (respectively) from the participants' written reports for Q1 of the Phantom Vanish Trick (. To fit the three simple linear regression models, the error structure of the residuals need to be normal and heteroskedastic, satisfactory normality was achieved by applying a folded reciprocal transformation of the form: $\log((x + 1)/(101 - x))$ to the ratings. For each model, my categorization of the participants' reported experience of the PVI in Q1 for the Phantom Vanish Trick was used to predict the participants' ratings of Surprising (Q2), Impossible (Q3), and Magical (Q4) for the Phantom Vanish Trick. Models were fitted using the lm package in R (www.r-project.org).

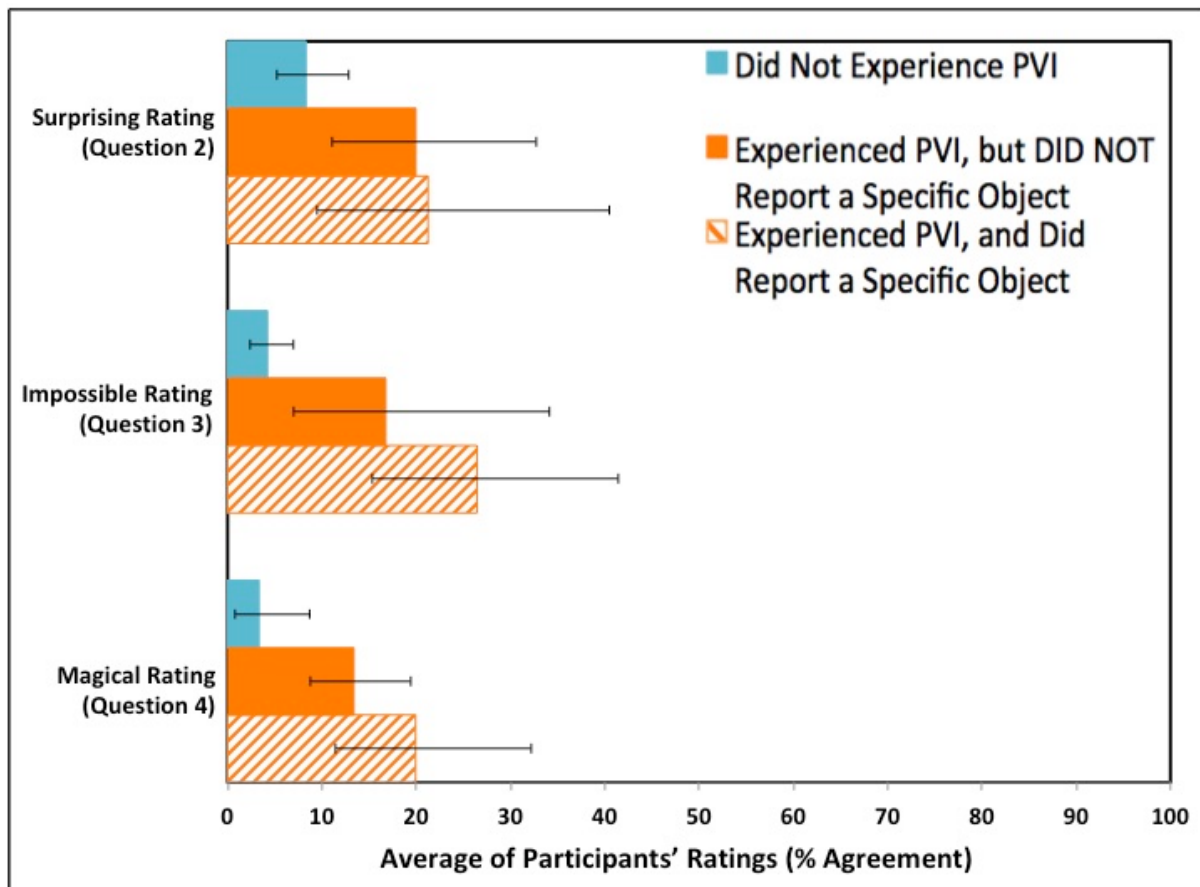


Figure 5.11. Average ratings of how surprising, impossible, and magical participants considered Video 5 (the Phantom Vanish Trick) comparing participants who did not report experiencing the Phantom Vanish Illusion (PVI) to those who did report experiencing the PVI. Error bars represent 95% Confidence intervals.

Surprise Ratings for the Phantom Vanish Trick

In the first of three linear regression models, participants' reported experience of the PVI (as categorized by their written responses to Q1) significantly predicted how Surprising they found the Phantom Vanish Trick (Q2), $R^2 = 0.05$, $F_{(2,122)} = 3.78$, $p = .03$. There was a significant difference between the Surprising ratings of participants who did not experience the PVI ($M = 8.31$, 95% CI [5.16, 12.84]) and participants who did experience the PVI but did not report a specific object ($M = 21.25$, 95% CI [9.40, 40.48]), $t(122) = 1.99$, $p = .04$, as well as between participants who did not experience the PVI and participants who did experience the PVI and did report a specific object ($M = 26.45$, 95% CI [15.39, 41.29]), $t(122) = 2.33$, $p = .02$. However, for participants who did experience the PVI, there was not a significant difference in the Surprising ratings between participants who did and did not report a specific object, $t(122) = 0.14$, $p = .88$. This analysis supports my prediction that the participants' written reports (Q1) for the Phantom Vanish Trick would be corroborated by their ratings of how Surprising (Q2) they found the Phantom Vanish Trick. Participants who were categorized (based on their written reports to Q1) as having reported experiencing the PVI rated the Phantom Vanish Trick as being more Surprising than those who were categorized as not having reported experiencing the PVI.

Impossible Ratings for the Phantom Vanish Trick

In the second of three linear regression models, participants' reported experience of the PVI (as categorized by their written responses to Q1) significantly predicted how Impossible they found the Phantom Vanish Trick (Q3), $R^2 = 0.16$, $F_{(2,122)} = 12.09$, $P < 0.001$. There was a significant difference between the Impossible ratings of participants who did not experience the PVI ($M = 4.23$, 95% CI [2.38, 6.97]) and participants who did experience the PVI but did not report a

specific object ($M = 16.78$, 95% CI [6.97, 34.13]), $t(122) = 2.62$, $p = .01$, as well as between participants who did not experience the PVI and participants who did experience the PVI and did report a specific object ($M = 26.45$ 95% CI [15.26, 41.52]), $t(122) = 4.68$, $p < .001$. However, for participants who did experience the PVI, there was not a significant difference in the Impossible ratings between participants who did and did not report a specific object, $t(122) = 0.97$, $p = .34$. This analysis supports my prediction that the participants' written reports (Q1) for the Phantom Vanish Trick would be corroborated by their ratings of how Impossible (Q2) they found the Phantom Vanish Trick. Participants who were categorized (based on their written reports to Q1) as having reported experiencing the PVI rated the Phantom Vanish Trick as being more Impossible than those who were categorized as not having reported experiencing the PVI.

Magical Ratings for the Phantom Vanish Trick

In the third of three linear regression models, I found that participants' reported experience of the PVI (as categorized by their written responses to Q1) significantly predicted how Magical they found the Phantom Vanish Trick (Q4, Video 5), $R^2 = 0.16$, $F_{(2,122)} = 11.56$, $p < .001$. There was a significant difference between the Magical ratings of participants who did not experience the PVI ($M = 3.33$, 95% CI [0.80, 8.70]) and participants who did experience the PVI but did not report a specific object ($M = 13.35$, 95% CI [8.83, 19.49]), $t(122) = 2.66$, $p = 0.01$, as well as between participants who did not experience the PVI and participants who did experience the PVI and did report a specific object ($M = 19.94$, 95% CI [11.36, 32.26]), $t(122) = 4.54$, $P < 0.001$. However, for participants who did experience the PVI, there was not a significant difference in the Magical ratings between participants who did and did not report a specific object, $t(122) = 0.83$, $p = .40$. This analysis supports my prediction that the participants' written reports (Q1) for the

Phantom Vanish Trick would be corroborated by their ratings of how Surprising (Q2) they found the Phantom Vanish Trick. Participants who were categorized (based on their written reports to Q1) as having reported experiencing the PVI rated the Phantom Vanish Trick as being more Magical than those who were categorized as not having reported experiencing the PVI.

Misinformation Analyses

I conducted a binary logistic regression analysis to examine whether participants' exposure to misinformation would predict how likely they were to have reported having witnessed a phantom object. Participants were either (a) exposed to no misinformation (b) exposed to a single item of misinformation or (c) repeatedly exposed to misinformation (condition 4). Models were fitted using the glm package in R (www.r-project.org). A test of the full model against a constant only model was statistically significant, indicating that exposure to misinformation reliably distinguished between participants who did and did not report phantom objects ($\chi^2(2) = 16.28, p < 0.001$, Naglekerke's $R^2 = 0.176$). Participants who were not exposed to misinformation were significantly less likely to report witnessing phantom objects compared to those participants who were exposed to a single item of misinformation, $t(122) = 1.96, p = 0.02$, OR = 7.07. Similarly participants who were not exposed to misinformation were significantly less likely to report witnessing phantom objects compared to those participants who were exposed to repeated misinformation $t(122) = 2.67, p = 0.001$, OR = 14.44. Participants who were exposed to a single item of misinformation were not significantly more likely to report witnessing a phantom object compared to participants who were exposed to repeated misinformation, $t(122) = 0.71, p = 0.122$.

5.7.4. Discussion

As with the original Phantom Vanish Paradigm (chapter 5), participants' ratings of the Phantom Vanish Trick corroborated their written reports. Participants who reported having seen phantom objects reported the trick as being significantly more magical and impossible than those who reported having veridical experiences (e.g. "he took nothing out of the cup and moved his hands"). These current results extend my previous findings by demonstrating that the Phantom Vanish Illusion is not necessarily attributable to perceptual priming. In the original experiment, participants watched four videos, each of which featured real objects, before they saw the Phantom Vanish Trick. Condition 1 of the current experiment was identical to the original paradigm, except that participants did not watch any videos before they saw the Phantom Vanish Trick. Nonetheless, 10 out of 35 participants reported that they had seen the magician present an object and make it disappear, despite the fact that they had *never* been presented with an object at any point during the experiment. These findings correspond with recent investigations of the vanishing ball illusion (Kuhn & Rensink, 2016).

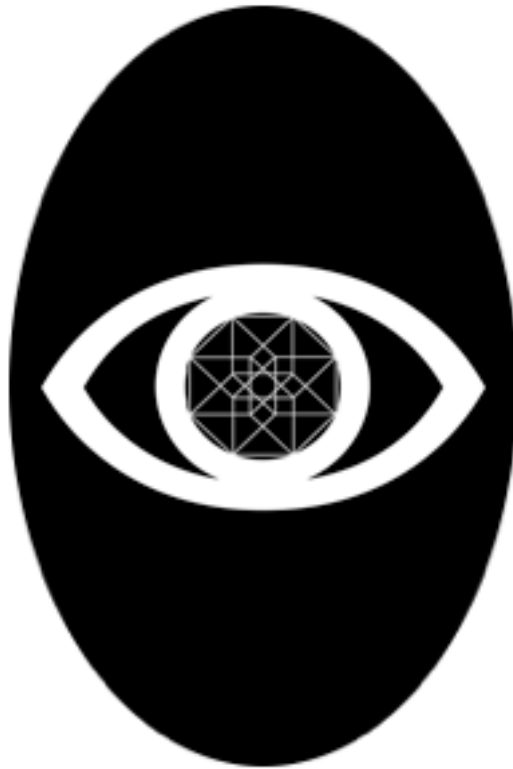
This experiment sheds new light on the concept of phantom objects that was first raised in chapter 5. I propose that the phantom objects that participants report are may be amalgamations of expectation based amodal perceptions and post-event inferences, which are themselves confused with veridical perceptual experiences. Such confusion is consistent with the theoretical concept of source monitoring errors (Johnson, Hastroudi, & Lindsay, 1993), or, more particularly, reality monitoring errors (Johnson & Raye, 1981; Johnson, 1988). Given the fact that true event, misinformation exposure, and participant reports occurred in a relatively rapid sequence (i.e. the false reports were generated less than a minute after the true events), these results support the idea that experiments on longer term

misinformation effects (e.g. Loftus & Palmer, 1974; Loftus, 2005)- in which false memories are thought to form over periods of weeks and days- may be integrated with faster simpler experiments on phenomenon like boundary extension (e.g. Inraub & Dickinson, 2008), which suggest that false memories can form in fractions of a second. Interestingly, these experimental results also integrate with a small body of neuropsychological literature: The neurologist A.R. Luria (1968), wrote an extensive case study of a patient, Mr. S, who exhibited symptoms of hypermnnesia (what might today be referred to as highly superior autobiographical memory). Mr. S's memories were so vivid he would sometimes struggle to distinguish between visual images that he was actively remembering and visual images that he was currently perceiving. He wrote to Luria that "To me there's no great difference between the things I imagine and what exists in reality" (quoted in Luria, p. 147). For example, he noted that he had difficulty reading the time on a clock face, because he could not be sure whether he was seeing position of the hands as they really were or how he remembered them being. While this is an extreme example, it nevertheless provides additional support for the idea that people can mistake top-down amodal perceptions (in this case generated from memory) for bottom-up sensory experiences.

Finally, it should also be noted that my present results should be considered preliminary, given the relatively small sample sizes, nonetheless this experiment does demonstrate that the Phantom Vanish Paradigm can be readily adapted to address novel questions related to memory and perception. The fact that the Phantom Vanish Illusion can be generated by presenting participants with only a brief set of written instructions and 19 second video clip shows that this can be a highly efficient method for collecting data about visual illusions in dynamic scenes.

Chapter 6

General Discussion



The preceding work has covered a range of material including historical reviews and novel empirical research, all based on the themes of magic, illusions, and invisibility. In chapter 1, I began by introducing three ways of looking at the concept of invisibility: (1) things that are hidden from sight, (2) things that are unable to be seen, and (3) things that are overlooked or ignored. I linked these three types of invisibility to three corresponding visual illusions: Illusions of omission, illusions of commission, and metacognitive illusions. The first way of looking at invisibility related to illusions of omission—failures to see things that are presented in plain sight. This theme was embodied throughout subsequent chapters by the concept of inattentional blindness (IB). The second way of looking at invisibility concerned illusions of commission—seeing things that are not really present—things that cannot be truly ‘seen’ in the sense that they do not actually exist. This theme was embodied by the concepts of amodal perceptions and illusory memories. The third way of looking at invisibility related to illusions of metacognition—failures of awareness about failures of awareness. This theme was variously embodied through the thesis by re-examinations of past experiments that had traditionally been overlooked by contemporary researchers and by the fact that modern experimental results related to illusions of commission and omission continue to surprise and, in some cases, literally unbelievable to participants. This final chapter will summarize historical and empirical research that has been presented. I will consider how these findings relate to the theoretical frameworks of attentional set theory and reality monitoring, and I will discuss the theoretical and methodological limitations, as well as potential future directions of the work. Finally, I will consider the broader implications of the metacognitive illusions about perception and seeing, and why magic is an effective tool driving future research and also a powerful tool for communicating existing ideas.

6.1. Summary of Historical and Experimental Findings

Chapters 2 and 3 consisted of historical reviews on the topics of inattentional blindness and magic. In keeping with the third type of invisibility (things which are overlooked or ignored) the majority of the works I reviewed were experiments or reports that have largely been overlooked by experimental psychologists. In chapter 2, *Ghosts of Gorillas Past*, I demonstrated that, despite the fact that the term ‘inattentional blindness’ was only introduced in the 1990s, empirical accounts of inattentional blindness-like phenomena can be found dating back more than 100 years. Beginning with Mack and Rock (1998) and Simons and Chabris (1999), I presented research findings demonstrating inattentional blindness for simulated airplanes (Haines, 1991) and artificial ghosts (Cornell, 1959; 1960). I revealed how Hugo Münsterberg (1907) had also developed a classroom demonstration of eye-witness testimony that can be re-considered as an inattentional blindness experiment. The earliest experiment discussed dated back to 1887, when two psychical researchers, Richard Hodgson and S.J. Davey produced a ‘Mal-Observation Report’ documenting errors of eye-witness testimony from participants who watched hoax-séances. I proposed that the errors reported by Hodgson and Davey are conceptually parallel to the look-but-fail-to-see errors that characterize inattentional blindness. I also argued that the experiments I presented were largely overlooked by perception researchers, and suggested that this could be attributed to the fact that they were reported outside of formal psychology journals and that their results contradicted intuitive ideas about visual awareness. By way of demonstrating that such historical considerations could directly inspire contemporary experimental research, I concluded my second chapter by reporting a modern-day adaptation of a paradigm first described over a 100 years ago by Hugo Münsterberg (1907). This

experiment represents a synthesis of the empirical and historical aspects of this thesis. Münsterberg had described a procedure in which students in his psychology lecture were apparently functionally blind to stimuli that were clearly visible and in plain sight. Based on Münsterberg's brief write-up, I created a 21st century version of his procedure and implemented it as part of one of my own psychology lectures. My results replicated Münsterberg's reported findings that participants can fail to report significant elements of a dynamic visual scene, even when these elements are displayed in a 'live' real-world setting and are central to where participants have been instructed to focus their attention. And I discussed how these results can be integrated with contemporary conceptions of inattentional blindness.

In chapter 3, *Methods from Madness*, I reviewed historical perspectives on magic tricks. Tracing accounts of magic trick related illusions from ancient Egyptians (Lichtheim, 1973) and Greeks (Woodcroft, 1851), through medieval discussions of witchcraft (Scot, 1584). I showed how accounts of magic tricks have developed in sophistication through time- from credulous accounts of impossible effects, to portrayals of magic trick methods, to specific prescriptions of how to use methods to accomplish magical effects. I also proposed that the psychological question of how people perceive magic tricks was central to the establishment of experimental psychology as a scientific discipline. I described how the founders of experimental psychology, including Wilhelm Wundt and William James had been closely involved with the spiritualist movement and psychical research, attempts to scientifically investigate supernatural phenomena like the communication with the souls of the dead. Wundt (1879), in particular, used the concept of magic tricks as a rhetorical device to dismiss contemporary theories, proposed by his colleague Johann Zöllner (1878). Zöllner argued that he had discovered physical evidence of spirit beings who

could influence our world from a fourth spatial dimension; while Wundt countered that Zöllner was being deceived by magic tricks, or jugglery. I suggested that this controversy inspired other early psychologists to turn their attention to the psychology of illusions and magic tricks, (Jastrow, 1888; 1896; Dessoir, 1893; Binet, 1894; Triplett, 1900), and I argued that a historical appreciation of these early works and their context can be beneficial for contemporary researchers who are interested in conducting research on the ‘Science of Magic.’

Following these historical chapters, I presented two chapters describing novel empirical research relating to inattentional blindness and illusory perceptions. Across multiple conditions, with complexity ranging from static line drawings, to recorded videos, to live events, I demonstrated that manipulating the relationships between viewer’s attentional set and visual events can variously in accurate perceptions, illusions of omission, and illusions of commission. In chapter 4, I reported the results of an inattentional blindness paradigm that involved using static stimuli to show that participants were generally able to report unexpected words when those words represented exemplars of a category that they were actively looking for. That is to say, when participants’ attentional set was semantically congruent with an unexpected stimulus, then participants’ perceptions of that stimulus were generally accurate and veridical. Conversely, I demonstrated that attentional set could result in illusions of omission (i.e., inattentional blindness) when unexpected stimuli were semantically incongruent with what the viewer was actively looking for. Additionally, I reported how I had administered a questionnaire that accompanied all of the inattentional blindness experiments conducted as part of this chapter. This questionnaire was designed to examine participants metacognitive evaluations of their experiences related to the inattentional blindness experiment.

Similar to past experiments that had been conducted for change blindness experiments (e.g. Beck, Levin, & Angleone, 2006; Levin, Momen, Drivdahl, Simons, 2010), I found that, in general, participants tended to over-estimate their own ability to detect the critical stimulus. Furthermore, neither participants' detection rates nor their beliefs about their own detection ability appeared appear to be significantly influenced by their knowledge of inattentional blindness. That is to say, in the context of this experiment, participants who had prior knowledge of IB were just as likely to fail to detect the critical stimulus as participants who had never heard of IB; and additionally, participants who had heard of IB were just as likely to express the belief that they could not have failed to see the critical stimulus as participants who had never heard of IB.

In chapter 5, I reported that viewers' attentional set could also induce illusions of commission. This work was inspired by my own work as a professional magician, as well as by historical (e.g. Triplett, 1900; see chapters 2 and 3) and contemporary (Kuhn & Land, 2006) examples of researchers adapting magic trick methods to investigate perception and cognition. In contrast to the experiments described in the previous chapter, which used simple computer displays of static line drawings, I adapted magic trick methods to produce video clips and live performances- dynamic visual stimuli that were closer to 'real-world' events. Participants in these experiments watched a magician perform a series of magic tricks. Each trick was presented separately, and featured a single prop (either a coin, a red ball, a poker chip, a silk handkerchief, or a crayon) and a single magic effect. Participants also watched a non-magical control 'trick' that featured an event designed to be surprising and unexpected, but not magical or impossible. After watching four video clips of magic tricks and one non-magic control video, all participants were then

shown a critical video—the Phantom Vanish Trick— which depicted the magician pantomiming the actions of making an object disappear. Despite the fact that no object was ever shown during the Phantom Vanish Magic Trick video, and participants were not exposed to any explicit misinformation about the presence of an object, around a third of our participants nonetheless reported that they had seen the magician make an object disappear. I suggested that these reports indicated that participants had perceived ‘phantom objects’ where none really existed, and I discussed how these findings related to the theoretical frameworks of ecological and inferential perception, and how they exemplified the way that magic trick methods can be used as tool for conducting experimental psychological research. I concluded this chapter by presenting a preliminary follow-up experiment. Inspired by contemporary media issues related to ‘alternative facts,’ this follow-up paradigm included instructional manipulations specifically designed to expose participants to misinformation about the events that occurred in the videos they watched (in contrast to the original paradigm, which had been specifically designed to eliminate possible sources of verbal or written misinformation). My results indicated that exposure to misinformation significantly increased the likelihood that participants would report having seen a ‘phantom object.’ Additionally, by reducing the stimulus set to a single video clip (the Phantom Vanish Magic Trick), I was able to demonstrate that neither perceptual primes nor explicit misinformation were necessary to induce the illusion of phantom objects for some participants. A small minority of participants, who watched the Phantom Vanish Magic Trick and were not exposed to any misinformation, nevertheless reported having seen objects where none had been presented.

6.2. Theoretical Implications: Attentional Set and Reality Monitoring

Across the broad scope of this project, all of the historical and empirical evidence I have presented has related to the role of the top-down process of attention and expectation on visual perception (and to peoples' metacognitive evaluations of this idea). The illusions discussed all relate to a problem that was succinctly laid out by Ulric Neisser: "We cannot perceive *unless* we anticipate, but we must not see *only* what we anticipate" (1972, p. 97, original emphasis). Neisser proposed that this anticipatory process could be conceptualized as involving *anticipatory schemata* (a concept he adapted from Bartlett, 1932). Later researchers (e.g. Most, Scholl, Clifford, and Simons, 2001) further refined these ideas and incorporated them with the concept of attentional set (Folk, Remington, & Johnston, 1992). I propose that this concept can be expanded from simply relating to noticing or failing to notice stimuli (i.e. illusions of omission), to encompass the concept of perceiving illusory stimuli (i.e. illusions of commission). In other words, for our visual system to process information it must be tuned from the top-down, based on an attentional set corresponding to the observer's goals, to be sensitive to particular types of stimuli. Across multiple paradigms, I have demonstrated that manipulating the relationships between viewer's attentional set and visual events can variously in accurate perceptions, illusions of omission, and illusions of commission. Generally, when participants' attentional set was congruent with novel stimuli, then their perceptions were generally accurate and veridical. In the experiments described in chapter 3, I used an inattentional blindness paradigm involving static stimuli to show that participants, across multiple conditions, were generally able to report unexpected words when the words represented exemplars of a category that they were actively looking for. Conversely, in the same experiments, I demonstrated that attentional set could result in illusions of omission (i.e., failures of awareness) when unexpected stimuli are incongruent with what the viewer was actively looking for. In chapter 4, I

demonstrated that viewers' attentional set can also induce illusions of commission within the context of dynamic visual scenes. So, on the one hand, illusions of omission (failures to see), like inattentional blindness, can occur when unexpected visual information is incongruent with this attentional set. On the other hand, an observer's attentional set can also lead illusions of commission (seeing things which are not really there)—this can occur when an observer's expectation of a stimulus that 'ought' to be present is mistaken for an actual stimulus, as I argue was the case for participants in my Phantom Vanish experiments. In the case of both the illusions of omission and illusions of commission, metacognitive errors can result from observers overestimating the veracity of their precepts—observers either assume that they will only fail to perceive stimuli, if there are no stimuli there, or assume that their perceptions correspond with real stimulus, and they could never mistake an imagined stimulus for a real one. Thus, these illusions can all be conceptualized in terms of source monitoring errors (Johnson, Hashtroudi, & Lindsay, 1993), specifically, errors of reality monitoring (Johnson & Raye, 1981; Johnson, 1988).

6.2.1. Limitations and Future Directions

Beyond the particular limitations of the paradigms discussed in the previous chapters, one inherent limitation across all the empirical work I conducted was that my measures of stimulus detection rates were always based subjective reports provided by participants that were collected after the stimuli had been presented. While these reports were always elicited within seconds of the stimulus presentation, it is nonetheless theoretically possible that some of my attempts to measure perceptual experiences were confounded by participants' memory processes. In the case of the inattentional blindness experiments in chapters 4 and 6, one might argue that participants who failed to report the stimuli actually perceived the stimuli

(written words or the physical objects) at the time they were presented but then rapidly forgot them by the time they were questioned. Such an alternative hypothesis has been described ‘inattentional amnesia’ (Wolfe, 1999). Similarly, perhaps participants who reported having seen ‘phantom’ objects during the experiments described in chapter 5 did not actually ‘perceive’ those objects while they were watching the videos, but rather misremembered the videos when asked to subsequently describe them. Indeed, such an interpretation is at least partially supported by the results of my follow-up experiments described in at the end of the chapter. These experiments demonstrated that exposure to post-event misinformation resulted in increased reports of phantom objects. Because this manipulation took place *after* participants had viewed the critical video, it could not have influenced the way they perceived the video as they saw it, but rather must have influenced their subsequent recall. Even in the instances that I controlled for the influence of misinformation by deliberately asking open ended questions and by asking those questions immediately following the stimulus presentation, my participants answers relate to their very recent memories of their own perceptual experiences. However, within these limitations these results are still interesting because they nonetheless measure what people believe their experiences were.

Looking forward, each of the paradigms I described in the previous chapters have great potential individually for future research. The inattentional blindness paradigm reported in chapter 5 can be easily adapted to explore the relationships between attentional set on other types of semantic relationships, especially considering my finding that the experiment is sensitive to semantic congruency effects even when the entire stimulus set is reduced to the presentation of a single slide. One of the limiting factors in all inattentional blindness research is that,

because the critical stimulus must be unexpected, participants who are recruited can each only provide data for a single critical trial. This limitation was particularly relevant for the more ambiguous null results that I reported in chapter 4- it is possible that increasing the samples of each condition beyond 20 participants might reveal additional nuances related to semantic congruency and functional associations- and running shorter versions of the experiment on an online platform would be a much more efficient way of further exploring these questions. The Phantom Vanish Paradigm can likewise be adapted to explore the influence of different perceptual primes (by manipulating the preceding videos) and different types of instructional manipulations, as exemplified by my misinformation experiment, described in chapter 6. And Münsterberg's Eyewitness demonstration represents a new way to study the relatively underexplored concept of 'live' inattentional blindness- simple changes to the original set-up such as introducing an explicit primary task (e.g. 'Count the number of times the color of the screen changes on the tablet'), and explicitly asking about the critical stimulus (e.g. 'Did you see the experiment do anything in addition to holding the tablet?') could bring the paradigm in-line with more contemporary inattentional blindness experiments.

It's Not (Just) a Trick! Metacognition, Magic, and Real Consequences

The most consistent theme of this thesis has been that many people find the fact that they can be subject to illusory experiences to be unbelievable. Magic tricks provide a entertaining and engaging way of demonstration that this overconfidence is a metacognitive illusion. However, the consequences metacognitive illusions can be significant and even deadly in real world consequences. For example, motorists who do not realize that they can be intentionally blind may not realize that they could

be at risk of being involved in look-but-fail-to-see vehicular accidents (e.g. Hill, 1980; Herslund & Jørgensen, 2003). Failures of attention may contribute to serious errors by medical professionals engaged in high stakes procedures (e.g. Grissinger, 2012; Greig, Higham, & Nobre, 2014). And within legal systems across the world, are arguably over-reliant on eye-witness testimonies. In extreme cases, people's memories of their own perceptual experiences can be used as the basis for convictions and even criminal executions. The Innocence Project is a US-based charity that seeks to identify and over-turn erroneous criminal convictions, often by uncovering exonerating DNA evidence. Since 1992, they have successfully exonerated 324 falsely convicted individuals, and in 70% of these cases, eye-witness misidentifications served as the central evidence for the convictions (Eyewitness Misidentification, 2018). Magic can potentially provide researchers with a toolkit to fill-in conceptual gaps between less ecologically valid basic research and more practical real-world problems.

While it might not be feasible or even possible to train or educate people in ways that would allow them to 'overcome' perceptual illusions, perhaps it might be more practical to teach them to change their attributions about their experiences, to directly address the metacognitive components of the experience. Just as magic represents a powerful resource for researchers, inducing illusory experiences in laboratory settings, perhaps it could also be used as a tool for communicating and illustrating psychological concepts. It's one thing to explain to someone that their perceptual systems may be prone to particular sorts of errors, but it's another thing to illustrate one of these illusions in a vivid and realistic fashion. That being said there is currently a dearth of research on the effectiveness of magic as a teaching tool. I believe that this represents a promising and potentially important new avenue of

research, and that future studies should be conducted to investigate how magic can be used as a tool to promote critical thinking and educate people about metacognitive illusions.

6.3. Contemporary Controversies related to the ‘Science of Magic’

The recent development of a contemporary ‘Science of Magic’ based research program within psychology has not been entirely without controversy. The major criticisms levelled at the endeavor can be divided into three types. The first type of criticism is a historical one, historians of magic and psychology (Lamont & Henderson, 2009; Lamont, Henderson, & Smith, 2010) have asserted that some contemporary researchers (e.g. Macknick, et al., 2008) have erroneously suggested that they themselves are the first psychologists or neuroscientists to consider magic illusions in a laboratory context, while, in fact, magic has arguably been a subject of interest for psychologists for as long as psychology has been established as a formal scientific discipline (e.g. Wundt, 1879). The second criticism is directed towards researchers’ recent attempts to create a comprehensive taxonomic classification of magic tricks (e.g. Macknick, et al. 2008; Kuhn, Caffaratti, Teszka, & Rensink, 2014). Magic historian and magician, Dr. Peter Lamont, has argued that attempts to establish a formal ‘Science of Magic’ cannot be successful if they hinge on such classifications (Lamont, 2016a, 2016b). A third criticism is one that often originates from magicians themselves (e.g. Teller, 2012). Some magicians have argued that a Science of Magic led by academic researchers is impractical because psychologists and neuroscientists are too ignorant about the mechanisms behind magic tricks to properly study them, furthermore they point out that collaborations between scientists and magicians are necessarily one-sided, which magic serving to advance researchers’ science while the science does nothing to advance magicians’ magic.

Proponents of the first criticism rightly point out that psychological interest in magic is not new, and that this interest has generally not led to novel research. The interest can be traced to the turn of the 20th century (Wundt, 1879, Jastrow, 1888, 1896; Dessoir, 1893; Binet, 1896; Triplett, 1900), and the subsequent century has been marked by periodic articles noting that magic is an interesting a neglected field (e.g. Ciellier, 1922; Kelley, 1947, Kelly, 1977; Solomon, 1980; Gregory, 1982; Nardi, 1984). However, most of these writings were theoretical commentaries, rather than actual empirical research. This observation, that numerous psychologists and neuroscientists have expressed interest in magic, but very few have produced meaningful empirical work, has led some authors to argue that the Science of Magic is itself a fundamentally misguided idea. A contemporary instance of this issue can be observed in the idea of ‘neuromagic.’ Some researchers have asserted that the latest Science of Magic trend is novel because it incorporates contemporary neuroscientific approaches. The concept of ‘neuromagic’ has been featured in *Nature Reviews Neuroscience* (Macknik et al., 2008), been the subject of a science book geared towards general audiences (Macknik, Martinez-Conde, & Blakely, 2010) and has received significant coverage popular science journals and the general media (having been featured in, for example, *Scientific American*, *The New York Times*, *The Wall Street Journal*, *The Chicago Tribune*, *The Boston Globe*, *USA Today*, *ScienceNews*, *Der Spiegel*, *The Scientist*, *New Scientist*, and *Wired*). However, over the past 8 years since the term ‘neuromagic’ was introduced, there have been a total of 3 published experiments that have actually examined the neural correlates of magic trick perception. The first (Parris et al., 2009) used fMRI paired with videos of magic tricks in an attempt to isolate the neural correlates of the ‘illusion of impossibility.’ While this study arguably represents a promising novel approach to investigating the neural correlates of beliefs, methodological constraints limited the

researchers' ability to dissociate between videos represented surprising events and videos representing magical or impossible events. The second (Daneck et al., 2015) was a partial replication of the first fMRI experiment, which empirically demonstrated that the magician who performed the magic perceived the tricks differently than naive viewers. The third study (Caffaratti, et al., 2016) used EEG recordings paired with videos of magic tricks adapted from the classic 'cups and balls' trick to examine expectation violations. While the study does represent an interesting and pioneering effort to measure and analyze EEG responses to continuous video stimuli, in terms of revealing new information about magic illusions, it simply demonstrated that viewers who see a ball apparently disappear from beneath a cup exhibit neurological responses consistent with an expectation violation. In summary, the neuromagic approach has yet to live up to its stated promise of being "more productive... than previous attempts at psychological magic theory" (Macknik & Martinez-Conde, 2009, p. 241). However, while neuromagic specifically has been relatively unproductive, the more general idea of adapting magic trick methods to psychology experiments has recently proved to be productive, with researchers adapting magic tricks to further illuminate a wide variety of cognitive mechanisms, including inattentional blindness (e.g., Kuhn & Tatler, 2005; Kuhn & Findlay, 2010, 2011; Barnhart & Goldinger, 2014), change blindness (Smith, Lamont, & Henderson, 2012, 2013; Kuhn, Teszka, Tenaw, & Kingstone, 2016), introspection (Johansson, Hall, Sikstrom, & Olson, 2005); decision making (Olson, Amlani, Raz & Rensink, 2015; Shalom, 2013), problem solving (Daneck, Fraps, Von Mueller, Grothe, & Öllinger, 2014), memory (Daneck, Fraps, Von Mueller, Grothe, & Öllinger, 2013; Wilson & French, 2014), amodal perception (Ekroll & Beth, 2013; Beth & Ekroll, 2015; Tompkins, Woods, Aimola Davies, 2016). There have been more than 4 times as many empirical peer-reviewed articles involving magic published

since the year 2000 (55) compared to all the years prior (11 total between 1887 and 1997). These numbers strongly indicate that scientists have begun to move on from cursory examinations and opinion pieces.

The second type of criticism, relating to the taxonomic classification of magic tricks, is more problematic. On one hand, critics have made well-reasoned points about the difficulty of classifying magic into coherent and universal categories (Lamont, 2016a, 2016b, Lamont, Henderson, & Smith, 2010). In the terminology generally adopted by professional magicians, a ‘trick’ refers to both an ‘effect’ and a ‘method.’ Where the effect refers to the subjective experience of the spectators, and method refers to the mechanisms by which the effect is achieved. For a trick to be successful, the performer must conceal the true method behind the effect; the manipulations that accomplish this concealment can be referred to as ‘misdirection.’ One follow-up approach has been to further subdivide magic effects into nine separate categories (see Table 6.1), however the methods used to accomplish these effects are numerous and varied enough to defy a coherent classification.

Table 6.1.

Nine Types of Magic Effects (adapted from Lamont & Wiseman, 1999; Macknick et al., 2008)

Type of Effect	Description	Example
Vanish	An object disappears inexplicably into nothingness	A coin inexplicably vanishes from the magician's hand
Appearance	An object appears inexplicably from nowhere	A rabbit appears from an empty top hat
Transposition	An object moves to an impossible location; or two objects trade places	A borrowed note disappears and is found inside a lemon; or The Metamorphosis illusion, where a magician, who has been locked in a trunk appears to instantly change places with an assistant.
Restorations	An object that was destroyed is made whole again	A newspaper is torn and put back together again
Penetrations	Solid matter appears to pass through solid matter	A magician links a pair of solid steel rings
Transformations	An object impossibly morphs – changing size, shape, color, etc.	A playing card held at the finger tips changes color and suit
Telekinesis	Causing an object to float in defiance of gravity or to bend without apparently touching it	The magician appears to float off the ground with no support.
Extrasensory Perception (ESP)	Includes: Clairvoyance (gain information by means other than the known senses); Telepathy (mind reading); Precognition (predicting the future)	A magician might identify a chosen playing card by reading the spectators mind.
Extraordinary Feats	Encompass physical and mental stunts	The magician apparently stops his own pulse

Additionally, there are not necessarily direct relationships between methods and effects, in that the same method can be used to accomplish multiple effects (e.g., Lamont, 2016). For example, the false transfer method, where a magician pretends to pass an object from one hand to the other while actually retaining it in his first hand (see Appendix B for additional detail) can be used to accomplish a vanish (the object is gone), a transposition (the object impossibly 'jumps' from one hand to the other), or a penetration (the object might appear to pass through a solid table top). In each

instance, the method, retaining the object in the hand, remains constant. Another example of a proposed classification is Rensink et al.'s (2015) taxonomy of misdirection, which has been criticized as being "merely another way of arranging remarkably fuzzy concepts" (Lamont, 2016, p. 3). Proponents of these classification efforts acknowledge that such systems are inevitably highly subjective, but maintain that these classifications are both possible and useful for guiding future research. While the usefulness of taxonomies is currently an abstract debate, subsequent work will ultimately demonstrate (or fail to demonstrate) their utility for researchers. Both sides of this particular debate do consistently agree that the practice of adapting magic tricks can provide researchers with powerful new tools to investigate psychological questions, and this consensus is currently being borne out in ongoing published literature. I propose that this particular debate comes down to a semantic discrepancy of between what different authors think that the phrase 'Science of Magic' should entail. The question relates to philosophy of science and the nature of disciplinary boundaries. Hyman's (1989) distinction between 'hard' and 'soft' sub-disciplines. Hyman suggested that 'psychology of perception' or the 'psychology of memory' could be conceived of as examples of hard sub-disciplines. They hold together conceptually and deal with distinct and coherent psychological phenomena. In contrast, he suggested that 'psychology of law' or 'psychology of work' are examples of soft sub-disciplines. These labels do not imply that these areas are coherent and sets of psychological propositions, but rather various aspects of them can be understood in terms of existing psychological subfields. No 'psychology of magic' currently exists in a strong sense, however existing sub-fields of psychology including the psychology memory, attention, and decision making can all be used to address various aspects of the psychology of magic. It seems that some on one level the utility of magic as a 'hard' sub-discipline is what has actually been debated in the

literature. While I believe that each side of that debate might agree that the psychology of magic can qualify as a sub-discipline in the ‘soft’ sense.

The third criticism originates of non-scientist magicians who are skeptical of qualifications of scientists to make expert judgments about magic related topics. The position is nicely exemplified by an essay written by Raymond Teller (of the magic duo Penn & Teller) (Teller, 2012). The tagline of this article is “Neuroscientists are novices at deception. Magicians have done controlled testing in human perception for though sands of years.” Teller notes that he has been invited to co-author papers (e.g. Macknik et al., 2008) and delivered keynotes at scientific conferences, and that he is unimpressed by the idea that contemporary science might help to develop magic any further than magicians have already. Part of Teller’s disillusionment with idea of the ‘Science of Magic’ may be due to the fact that his own experiences have been closely linked with the relatively less productive ‘neuromagic’ approach. Additionally, several published studies (Cui et al., 2011; Rhiro et al., 2013) have emphasized results than specifically contradict magician’s intuitions about their own performances, sometimes making overly broad generalizations between ‘real world performances’ based on their more artificial laboratory paradigms. Teller explicitly asserts that the trial-and-error methods by which professional performers develop their tricks is equal to or superior to empirical laboratory studies. While it’s important to acknowledge that magicians have been developing magic tricks for at least as long we can trace recorded history, Teller’s argument in this interview fails to account for some crucial differences between the scientific method and performance magic. Firstly, while magicians may have developed methods for generating robust illusory experiences, this does not mean that they have a deep understanding of the underlying cognitive mechanisms that drive these illusions (such an understanding

is, in many ways, irrelevant to the process of replicating the effects). This is partially a consequence of how magicians develop their magic tricks. Developing tricks through performances is an inherently limited undertaking. Because magicians are professional entertainers, they are highly disincentivized from exploring relatively ineffective methods, which might nonetheless be of interest to researchers. Generally, a performer will only keep a trick their set if it is as close as possible to being 100% reliably effective, to this end it's good practice to include layers of different methods to maximize the chances of successfully inducing an effect. However, this means that magicians cannot necessarily be sure of the precise contributions of each method to the effect. Researchers, in contrast, are not constrained by the need to entertain participants- laboratory participants get paid to engage with the experiments, rather than the other way around. Thus, experiments can examine reduced versions of magic tricks that might produce effects that are considerably less robust than tricks that would be used in performance settings. Additionally, as artists, magicians can benefit generally from enriching their knowledge of topics related to their craft, even if the utility is not always immediately apparent (Tamariz, 2017).

Overall, I would like to think that work presented in this thesis embodies the idea of approaching the study of magic as a soft sub-discipline of psychology. The first two chapters demonstrated how the examination of magic history can offer new perspectives on the history of science and psychology, particularly in the areas of attention and perception. And subsequent empirical chapters (especially chapters 5 and 6), showed how magic trick methods can be adapted to develop novel research paradigms to investigate human perception and memory. Throughout the years I have been working this project, I believe my interest in magic has helped enhance my

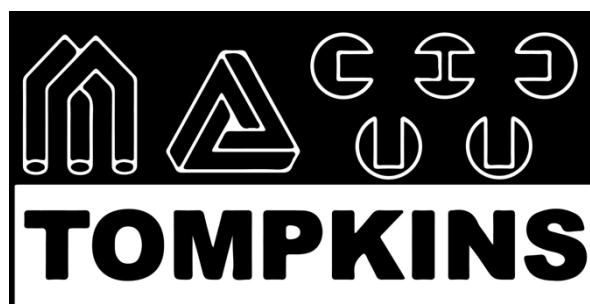
work as a scientist while my scientific research has also helped develop as an artist, in terms of my work as a magician.

6.4. Conclusion

In conclusion, I would like revisit the Wundt-Zöllner debate one final time. In one of his final reports on Henry Slade, Zöllner (1881, p. 57) asserted that all attempts to ascribe naturalistic explanations to the seemingly miraculous phenomena demonstrated were “scarcely less wonderful than are the facts themselves.” By this stage of his research, he believed that the fourth dimensional spirit people qualified as ‘facts.’¹⁸ In context, Zöllner clearly meant this line to be read as a dismissal of such natural explanations. He believed that, on balance, fourth dimensional spirits were more plausible than the fact that he and others might have experienced such vivid illusory phenomena. After all, he and his physicist colleagues were expert observers, so surely their perceptions could be trusted. To think that they could all have been deceived so thoroughly, he argued, was completely absurd. He asserted that Wundt’s attempt to ascribe Slade’s feats to ‘jugglery’ was intellectually dishonest. And indeed, Wundt did fail to offer any form of mechanistic explanation, other than to suggest that slight-of-hand could have been involved, in some way. Wundt even admitted that he himself was no expert in slight-of-hand. Whereas Zöllner had gone so far as to obtain a signed affidavit from a professional conjurer,

¹⁸ A last footnote: Given it was published in an English journal, the Bodleian holds an original copy of Zöllner’s 1878 article. When I went to the library to collect the journal, the librarian at the desk was apologetic. She explained that although it was listed in the catalog, the item I was interested in was actually missing from its assigned shelf space. Disappointed, I asked if she wouldn’t mind checking again. After very kindly agreeing to humor me, she returned, a few minutes later, with the journal in hand. She told me that she had found the book in its proper place- *precisely where her colleagues said that it wasn’t*. So, the journal, containing a scientific treatise on mysteriously vanishing and reappearing objects, had itself allegedly vanished from its assigned shelf, only to reappear.

Samuel Bellachini, who swore that Slade's feats could not possibly be magic tricks (cited in Zöllner, 1881). I personally think that Zöllner's weighting of the evidence is problematic. Although as Mr. Munton (Slade's defense attorney at his London trial) argued eloquently and futilely— just because I might know some ways of reproducing effects that *look* like Slade's feats using slight-of-hand, does not mean that I can ever *prove* that Slade, back in 1877, did not possess supernatural powers. Ultimately, one can only judge the weight of evidence. I do believe that Zöllner was, perhaps inadvertently, touching on something profound about experimental psychology when he suggested that the naturalistic explanations were 'more wonderful' than his supernatural ones. Such natural explanations represent an evolution in our scientific understanding of how the people perceive and remember the world around them. To me, the fact that people can experience these illusions and be so consistently surprised about them, is indeed a much more satisfying and 'wonderful' explanation. In Wundt's defense, his argument about the psychological implications of magic tricks and illusions was necessarily vague, because experimental psychology itself barely existed. I would like to think that empirical research I have been able to conduct was in some ways built on the legacy of this debate. And I think that contemporary 'renaissance' of Science of Magic research supports Wundt's suggestion that magic tricks can be a useful tool for researchers. Not only can magic tricks help researchers develop new avenues of research, but I think that magic can also serve as useful vehicle for communicating new and existing research findings about the psychology of perception. I am looking forward to future magic-inspired developments in experimental psychological research.



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Appendices

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Appendix A: A Science of Magic Bibliography 1888-2016

In the past 15 years, the scientific investigation of magic has undergone something of a renaissance. Since the year 2000, the body of experimental scientific literature on the topic of performance magic has more than quadrupled, in comparison to all of the experimental work published in preceding two centuries. 57 empirical papers have been published on the topic within the last 15 years, compared to the 12 that were published between 1887 and 1999. While the recent level of focus on the topic is arguably relatively novel, the idea of studying the psychology of magic can traced back at least as far as concept of psychology itself.

The following is a complete list of published psychology experiments that relate to either magic tricks or magicians, in order of publication. The list is limited to reports of empirical experiments and does NOT include reviews, commentaries, theoretical papers, or surveys. Furthermore, the list only includes studies involving adult participants. The reason for this is that there is a significant body of developmental literature examining concepts like object permanence that utilizes concepts that are often somewhat analogous to magic tricks. However, such experiments do not necessarily self-identify as relating to magical experiences, and my own experimental work has focused exclusively on adult perceptions.

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Appendix B: A Case Study in How to Vanish A Coin

He that hath once attained to the facilitie of retaining one piece of monie in his right hand, may shew a hundreth pleasant conceits by that means, and reserve two or three as well as one. And lo then may you seeme to put one peice into your left hand, and reteining it still in your right hand, and may so with words seeme to bring both peeces together... By this device (I saie) a hundredth conceits may be shewed. (Scot, 1584, p. 184)

If you're working to create the illusion that the coin has vanished; it's meaningless to talk about 'where the coin is.' It isn't anywhere. (Ortiz, 2005, p. 31).

Overview of the False Transfer Method

One of the first effects many magicians learn to perform is the 'vanish' of small object. A vanish is effectively magical when the object seems to disappear without any apparent explanation. "The earliest English language description of a coin vanish can actually be traced to *The Discoverie of Witchcraft* (Scot, 1584). Scot describes a technique that can broadly be referred to as a false transfer. The magician appears to move the coin from one hand to the other while secretly retaining it in the first hand. In this instance the method is the retention, while the effect is the vanish. Misdirection is applied in leading the spectator to believe there is a coin where none exists. The 'secret method' of the effect— that the coin is retained in the first hand by a minute flick of the fingers, is deceptively simple. The real performance of the vanish is actually carried out by the entire body. For example, imagine the magician is attempting to perform a vanish by apparently transferring a coin from his right hand to his left. Immediately following the false transfer, the right hand (which secretly holds the coin) relaxes and drops to the side, while the left hand (where the coin is *supposed* to be) is held up in such a way as to imply it contains an object. When it comes to 'pantomiming' actions involving held objects, magicians do not exhibit the same kinematic biases that are typical of non-magicians (Cavina-Pratesi, et al. 2011). For example, when grasping a real object, it is necessary for a person's grip to 'overshoot' the object's size so as to reach around past the edges of the object. When pretending to grasp an object, non-magicians neglect this grip overshoot

whereas trained magicians, do not. Additionally, by deliberately directing his own eyes and head, the magician can focus his own gaze and apparent attention on the false location of the coin; this acting can function as a false joint attention cue (e.g. Nuku & Bekkering, 2008). Beyond gaze and grasp, laboratory studies have affirmed that seemingly innocuous details of body language can contribute to the illusion. For instance, an eye-tracking experiment demonstrated that moving the empty left hand in a curvilinear fashion is more convincing than moving it in a straight line (Otero-Milan et al., 2011). All these factors combine to convince the spectators that the coin is really disappearing from the left hand (despite it never having been there to begin with). To the spectators, the ‘vanish’ occurs at the moment the magician opens his left hand to reveal the coin is gone. Magicians may encourage this misperception by introducing an additional action intended to falsely correlate with the vanish, such as snapping their fingers or saying a ‘magic word.’ Such actions not only add temporal distance between the method and the effect, but they can also introduce an element of false causality to enhance the illusion.

Alternative Explanations e.g., ‘It’s in the other hand!’

Despite all of the above, the false transfer, by itself, even if performed flawlessly, is of somewhat limited utility for magic performances. Following the initial moment of surprise that the coin has apparently disappeared, most spectators, will quickly and automatically assume that the coin is really in the other hand. Should the coin actually be there, as it would be in the simplest iteration of the false transfer method, this will very quickly erode the illusion of impossibility.

One solution to this problem is to apparently cause the coin to ‘reappear,’ as in the cliché of pulling a coin from behind a child’s ear. Magicians have, of course, developed a vast array of techniques for ‘ditching’ the supposedly vanished coin. To effect a ‘complete vanish,’ wherein both hands can be shown apparently empty. These methods may take place before or after the effect is revealed. They include elaborate juggling-style feats of dexterity where the coin is secretly concealed in the apparently empty hand, or surreptitiously tossed into sleeves and pockets, or even ‘cuffed’ i.e. secretly dropped down a trouser leg. There are also mechanical mechanisms of varied complexity involving pulls or reels, and hooks or magnets. But among the simplest and ‘cleanest’ methods, that deviates the least from the above false transfer example, is the introduction of a ‘magic wand.’

Reimagine the above scenario, just up to the point after the magician has performed the false transfer of the coin. This time, instead of simply revealing that the coin is gone, he announces that, for the next trick he requires the use of a ‘magic wand.’ Using his right hand (which secretly contains the coin) he reaches into his pocket. He openly removes a pen AND secretly leaves the coin behind in the pocket. Next he announces that he will use the pen/magic wand to make the coin vanish. He waves the pen over his left hand before finally opening it to reveal the coin is gone. He can now show both hands completely empty, except for the pen. The use of the magic wand is an excellent example of how misdirection can be employed on a higher level than that of physical perceptions. The spectators do see the magician openly place his hand in his pocket, but he explains away the action by retrieving the pen. He actually announces that the coin will disappear after it’s gone. But, to the spectators, the effect begins after the method has succeeded thoroughly hiding the coin. If asked to describe the trick afterwards, spectators will most likely say something like the magician ‘brought out a pen’ rather than say that ‘he put his hand in his pocket.’ (e.g. Hodgeson & Davey, 1887; Cruys, Wagemans, & Ekroll, 2015). Their memory of the action is influenced by its apparent (false) intentionality.

Appendix C: Overview of Experimental Design and Hypotheses

Conditions 1 -4: Exemplars and Semantic Congruency.

Critical stimuli TRUCK and GRAPES were exemplars of each of the primary task categories: vehicles and fruits. This experiment was intended to extend Koivisto and Revonsuo's original paradigm to English speakers and to the categories of fruits and vehicles.

- Hypothesis 1: Participants would exhibit low rates of IB when the exemplar was semantically congruent with the primary task category: TRUCK when looking for a vehicles and GRAPES when looking for fruits, because semantic congruency modulates IB.
- Hypothesis 2: Conversely, participants would exhibit high rates of IB when the exemplar was semantically incongruent with the primary task category: TRUCK when looking for a fruits and GRAPES when looking for vehicles, because semantic congruency is necessary for modulating IB.

Conditions 5 & 6: Non-Exemplar Non-Functional Associates and Semantic Congruency.

Critical stimulus TRAFFIC was neither an exemplar nor was it functionally associated with either of the primary task categories. This extension of the original paradigm allowed for a more detailed examination of the breadth of attentional set for semantic category.

- Hypothesis 3: Participants would exhibit high rates of IB for TRAFFIC, regardless of whether they were looking for fruits or looking for vehicles, because semantic congruency is not, in itself, sufficient to modulate inattentional blindness

Conditions 7 & 8: Non-Exemplar Functional Associates and Semantic Congruency.

Critical stimuli RIDE, DRIVE, and STEER were not exemplars of either the primary task category or ignored category but were functionally associated with the vehicle category.

- Hypothesis 4: Participants would exhibit low rates of IB when the critical stimuli were functionally associated with the attended category: RIDE/DRIVE/STEER look for vehicles, because functional associations and semantic congruency together can modulate inattentional blindness.
- Hypothesis 5: Participants would exhibit high rates of IB when the critical stimuli were not functionally associated with the attended category: RIDE look for fruits, because semantic congruency is necessary for modulating IB.

Conditions 9-11: Non-Exemplar Functional Associates

Critical Stimuli DRIVE₁, DRIVE₂, and STEER were tested to further investigate hypotheses 4 and 5.

- Hypothesis 6: If participants exhibited lower rates of IB for DRIVE when it was accompanied by a car and truck instead of a bike and bus, then the critical slide pictures themselves may be priming participants to become aware of the words.

Conditions 12 & 13: No-Expectation Conditions.

Critical Stimulus GRAPES was presented to participants in a streamlined experiment that consisted of only the critical, divided, and full attention trials; participants were not exposed to any practice trials or non-critical experimental trials.

- Hypothesis 7: Participants would exhibit lower rates of IB relative to the ‘full experiment’ conditions because they were not perceptually primed to expect the fixation cross to remain in the center of the screen.

Conditions 1 -4: Exemplars and Semantic Congruency.

Critical stimuli TRUCK and GRAPES were exemplars of each of the primary task categories: vehicles and fruits. This experiment was intended to extend Koivisto and Revonsuo’s original paradigm to English speakers and to the categories of fruits and vehicles.

- Hypothesis 1: Participants would exhibit low rates of IB when the exemplar was semantically congruent with the primary task category: TRUCK when looking for a vehicles and GRAPES when looking for fruits, because semantic congruency modulates IB.
- Hypothesis 2: Conversely, participants would exhibit high rates of IB when the exemplar was semantically incongruent with the primary task category: TRUCK when looking for a fruits and GRAPES when looking for vehicles, because semantic congruency is necessary for modulating IB.

Conditions 5 & 6: Non-Exemplar Non-Functional Associates and Semantic Congruency.

Critical stimulus TRAFFIC was neither an exemplar nor was it functionally associated with either of the primary task categories. This extension of the original paradigm allowed for a more detailed examination of the breadth of attentional set for semantic category.

- Hypothesis 3: Participants would exhibit high rates of IB for TRAFFIC, regardless of whether they were looking for fruits or looking for vehicles, because semantic congruency is not, in itself, sufficient to modulate inattentional blindness

Conditions 7 & 8: Non-Exemplar Functional Associates and Semantic Congruency.

Critical stimuli RIDE, DRIVE, and STEER were not exemplars of either the primary task category or ignored category but were functionally associated with the vehicle category.

- Hypothesis 4: Participants would exhibit low rates of IB when the critical stimuli were functionally associated with the attended category: RIDE/DRIVE/STEER look for vehicles, because functional associations and semantic congruency together can modulate inattentional blindness.
- Hypothesis 5: Participants would exhibit high rates of IB when the critical stimuli were not functionally associated with the attended category: RIDE look for fruits, because semantic congruency is necessary for modulating IB.

Conditions 9-11: Non-Exemplar Functional Associates

Critical Stimuli DRIVE₁, DRIVE₂, and STEER were tested to further investigate hypotheses 4 and 5.

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- Hypothesis 7: Participants would exhibit lower rates of IB relative to the ‘full experiment’ conditions because they were not perceptually primed to expect the fixation cross to remain in the center of the screen.

Appendix D: Participant Instruction Materials from Chp. 4

Attend vehicles instructions that were read to participants

I am reading to you from a standardised information sheet, to ensure that all participants receive identical instructions for this study. The experiment takes between 5 and 10 minutes.

The study you are participating in is investigating 'The processing of rapidly presented information.' Before we start, could you please take a moment to make sure that your cell phone is silenced.

Your task will be to report the vehicles, and ignore the fruits.

[show Blank Slide] First you will see a blank screen. When I say "Go" press the spacebar to start the trial. Please wait for me to say "Go" because between trials I will be writing down your responses.

[point to Fixation Slide] After you hit the spacebar, A cross will appear. Fix your gaze on this cross.

[point to Picture Slide] Then Vehicles and Fruits will appear briefly. Look for the Vehicles, ignore the fruits. It is important for control purposes that neither of us speak when the pictures are on the screen. Wait for the pictures to go away and then

[point to the Blank Slide] When the blank screen appears, report aloud the names of the vehicles you just saw.

Let's have a quick practice; *[show Blank Slide]* When I say "Go" then you press the spacebar. *[show Fixation slide]* Fixate on the cross *[show Picture slide]* Look for the Vehicles, *ignore the fruits* *[show Blank slide]* Report Aloud the Vehicles.

Great. Just to recap. *[show Full Trial Diagram]* When I say Go you press the spacebar. You stare at the cross. You look for vehicles. And then after the screen goes blank report aloud the vehicles that you saw.

Just a reminder: You are free to pull out of the study at any time, and you don't need to give a reason why. At the end of the task, a debriefing session about the purpose of the research is available. Your feedback on the task and your experience is most welcome.

Do you have any questions? *[seat participant and clean chin and headrest.]*

Before we start, please make sure you are seated comfortably with your chin on the chin rest and your forehead pressed firmly against the forehead rest. You can adjust the height of the chair if you'd like. Are you comfortable? Okay. Now that you're in position, we will begin the first trial.

Attend fruits instructions that were read to participants

I am reading to you from a standardised information sheet, to ensure that all participants receive identical instructions for this study. The experiment takes between 5 and 10 minutes.

The study you are participating in is investigating ‘The processing of rapidly presented information.’ Before we start, could you please take a moment to make sure that your cell phone is silenced.

Your task will be to report the fruits, and ignore the vehicles.

[show Blank slide] First you will see a blank screen. When I say “Go,” press the spacebar to start the trial. Please wait for me to say “Go,” because between trials I will be writing down your responses.

[point to Fixation Slide] After you hit the spacebar, A cross will appear. Fix your gaze on this cross.

[point to Picture Slide] Then Vehicles and Fruits will appear briefly. Look for the fruits, ignore the vehicles. It is important for control purposes that neither of us speak when the pictures are on the screen. Wait for the pictures to go away and then

[point to the Blank Slide] When the blank screen appears, report aloud the names of the fruits you just saw.

Let’s have a quick practice;

[show Blank Slide] When I say “Go” then you press the spacebar. *[show Fixation Slide]* Fixate on the cross *[show Picture Slide]* Look for the fruits, ignore the vehicles *[show Blank Slide]* Report Aloud the fruits

Great. Just to recap. [*show Full Trial Diagram*] When I say Go you press the spacebar. You stare at the cross. You look for fruits and ignore vehicles. And then, after the screen goes blank, report aloud the fruits that you saw.

Just a reminder: You are free to pull out of the study at any time, and you don't need to give a reason why.

At the end of the task, a debriefing session about the purpose of the research is available. Your feedback on the task and your experience is most welcome.

Do you have any questions? [*seat participant and clean chin and headrest.*]

Before we start, please make sure you are seated comfortably with your chin on the chin rest and your forehead pressed firmly against the forehead rest. You can adjust the height of the chair if you'd like. Are you comfortable? Okay. Now that you're in position, we will begin the first trial.

Attend fruits instructions that were read to participants in the ‘no expectation’ condition

I am reading to you from a standardised information sheet, to ensure that all participants receive identical instructions for this study. The experiment takes between 5 and 10 minutes.

The study you are participating in is investigating ‘The processing of rapidly presented information.’ Before we start, could you please take a moment to make sure that your cell phone is silenced.

Your task will be to report the fruits, and ignore the vehicles.

First you will see a blank screen. When I say “Go,” press the spacebar to start the trial. Please wait for me to say “Go,” because between trials I will be writing down your responses.

After you hit the spacebar, A cross will appear. Fix your gaze on this cross.

Then Vehicles and Fruits will appear briefly. Fruit pictures will look something like this [*show fruit picture*], and vehicle pictures will look something like this [*show vehicle picture*]. Look for the fruits, ignore the vehicles. It is important for control purposes that neither of us speak when the pictures are on the screen. Wait for the pictures to go away and then- When the blank screen appears, report aloud the names of the fruits you just saw.

Great. Just to recap. When I say Go, you press the spacebar. You stare at the cross. You look for fruits and ignore vehicles. And then, after the screen goes blank, report aloud the fruits that you saw.

Just a reminder: You are free to pull out of the study at any time, and you don't need to give a reason why.

At the end of the task, a debriefing session about the purpose of the research is available. Your feedback on the task and your experience is most welcome.

Do you have any questions? [*seat participant and clean chin and headrest.*]

Before we start, please make sure you are seated comfortably with your chin on the chin rest and your forehead pressed firmly against the forehead rest. You can adjust the height of the chair if you'd like.

Are you comfortable? Okay. Now that you're in position, we will begin the first trial.

Attend vehicles instructions that were read to participants in the ‘no expectation’ condition

I am reading to you from a standardised information sheet, to ensure that all participants receive identical instructions for this study. The experiment takes between 5 and 10 minutes.

The study you are participating in is investigating ‘The processing of rapidly presented information.’ Before we start, could you please take a moment to make sure that your cell phone is silenced.

Your task will be to report the vehicles and, ignore the vehicles.

First you will see a blank screen. When I say “Go,” press the spacebar to start the trial. Please wait for me to say “Go,” because between trials I will be writing down your responses.

After you hit the spacebar, A cross will appear. Fix your gaze on this cross.

Then Vehicles and Fruits will appear briefly. Fruit pictures will look something like this [*show fruit picture*], and vehicle pictures will look something like this [*show vehicle picture*]. Look for the vehicles, ignore the fruits. It is important for control purposes that neither of us speak when the pictures are on the screen. Wait for the pictures to go away and then- When the blank screen appears, report aloud the names of the fruits you just saw.

Great. Just to recap. When I say Go, you press the spacebar. You stare at the cross. You look for fruits and ignore vehicles. And then, after the screen goes blank, report aloud the vehicles that you saw.

Just a reminder: You are free to pull out of the study at any time, and you don’t need to give a reason why.

At the end of the task, a debriefing session about the purpose of the research is available. Your feedback on the task and your experience is most welcome.

Do you have any questions? *[seat participant and clean chin and headrest.]*

Before we start, please make sure you are seated comfortably with your chin on the chin rest and your forehead pressed firmly against the forehead rest. You can adjust the height of the chair if you'd like.

Are you comfortable? Okay. Now that you're in position, we will begin the first trial.

Appendix E: Stimuli Sets from Chp. 4

Example Practice Stimulus (Conditions 1-11)



Example Stimuli Shown to Participants in Conditions 12-13

Example Vehicle Pictures

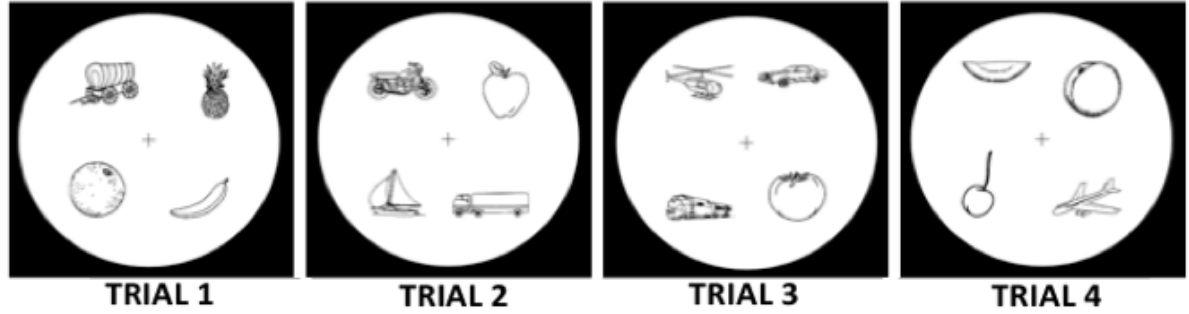


Example Fruit Pictures

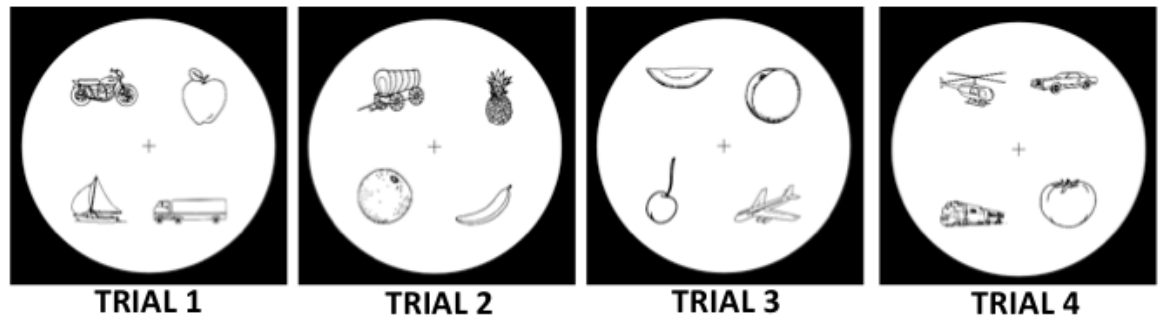


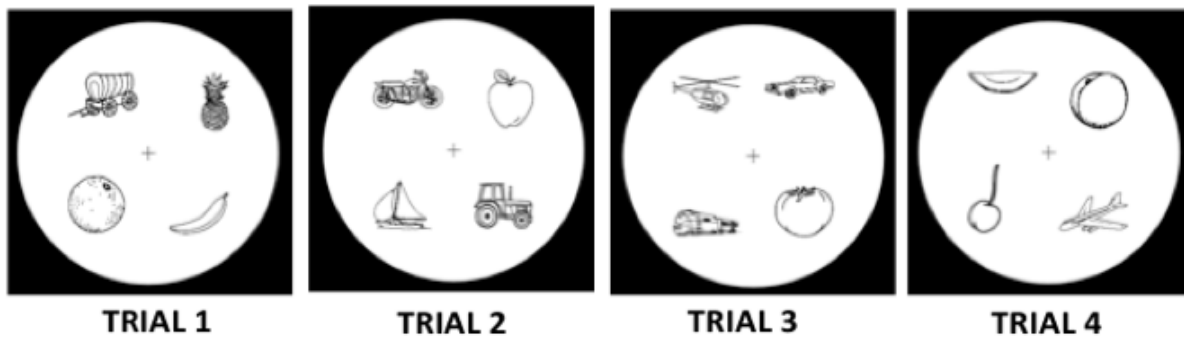
Primary Task Stimuli Conditions 3-9, 11

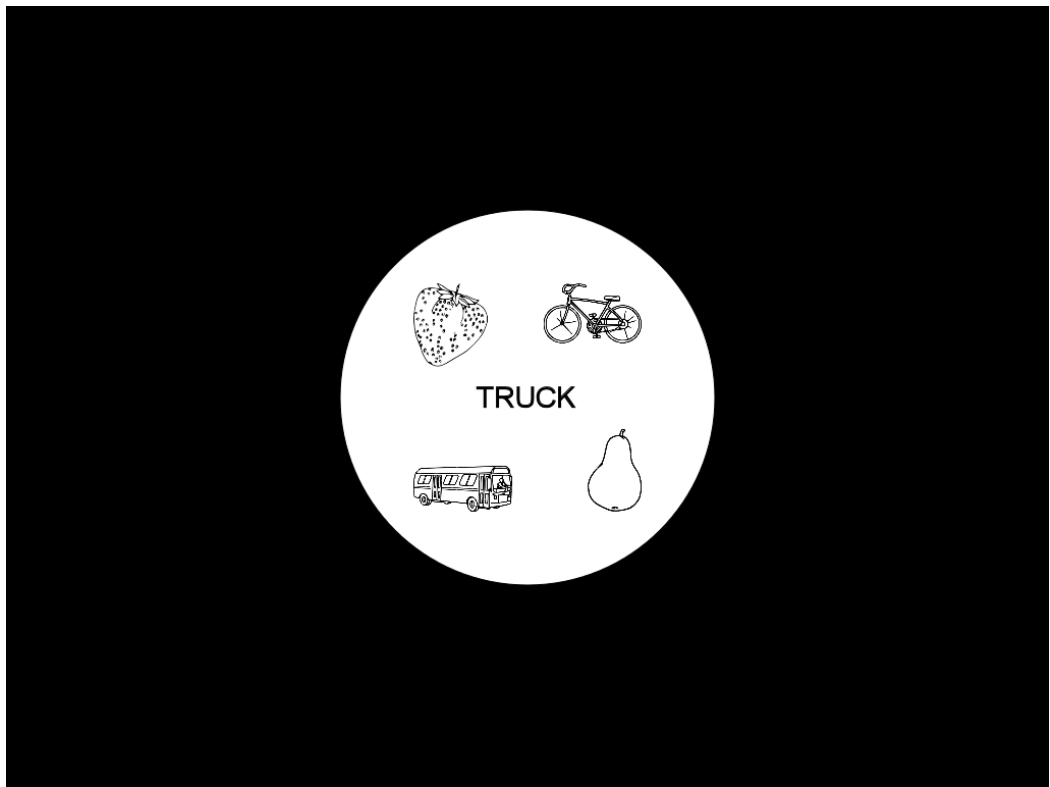
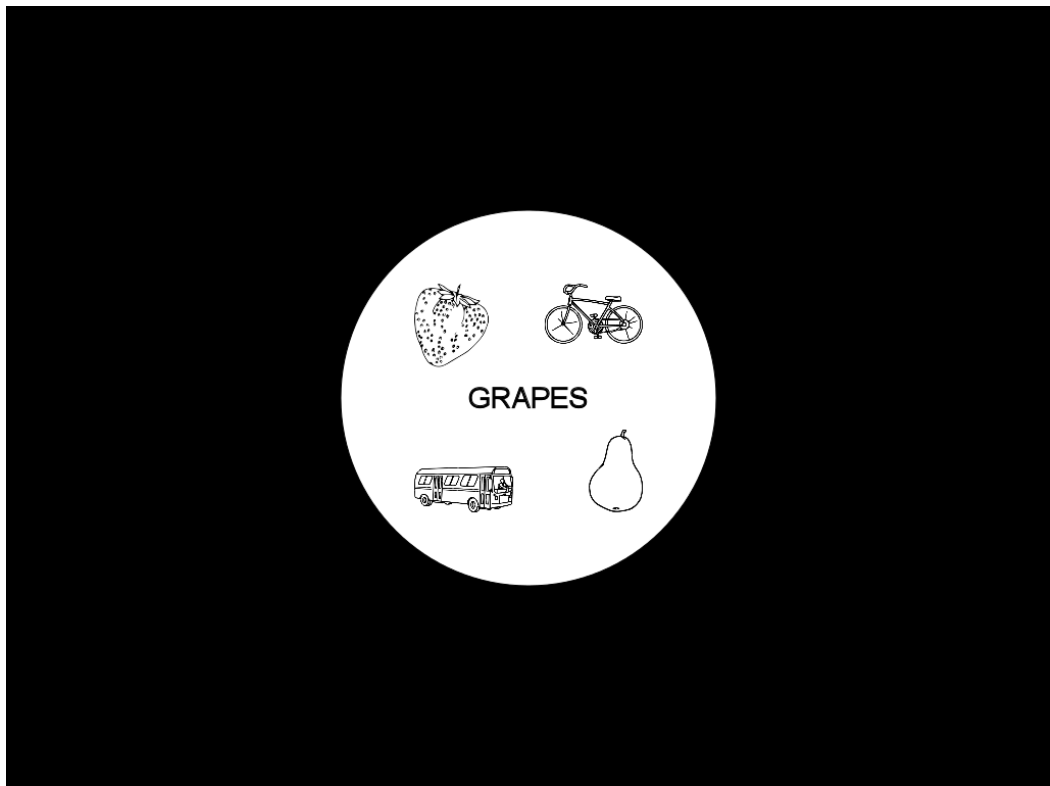
Trial Pattern 1



Trial Pattern 2

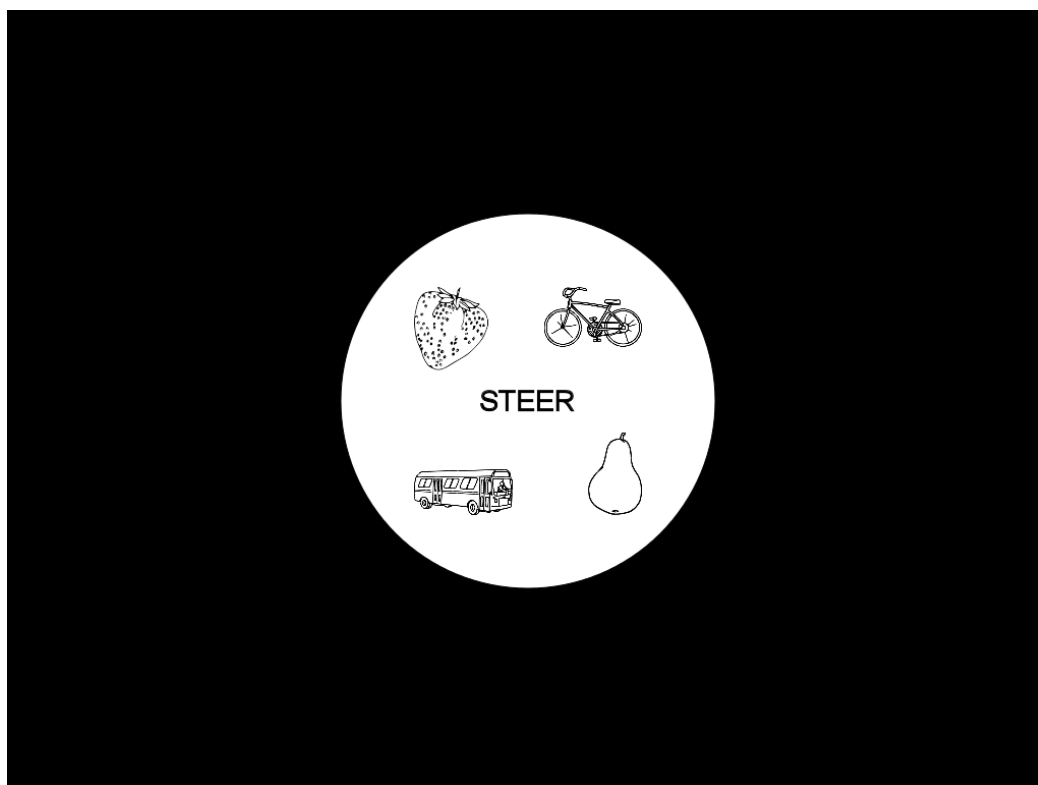


Primary Task Stimuli in Condition 10**Trial Pattern 1****Trial Pattern 2**

Critical Slide Conditions 1-2**Critical Slide Conditions 3-4, 12-13**

Critical Slide Conditions 5-6**Critical Slide Condition 7-8**

Critical Slide Condition 9**Critical Slide Condition 10**

Critical Slide Condition 11

Appendix F: Visual Analog Scales from Chp. 4

How **surprising** did you find the events shown in this video?
Please use your mouse to indicate your response on the
slider below.

not at all surprising  very surprising

To what extent did the events shown in this video seem to
you to be physically **impossible**? Please use your mouse to
indicate your response on the slider below.

not at all impossible  very impossible

How **magical** did you find the events shown in this video?
Please use your mouse to indicate your response on the
slider below.

not at all magical  very magical

Appendix G: Inspirations for the Phantom Vanish Trick

The idea for the Phantom Vanish video was initially inspired by my own work as a magician. I mostly worked ‘close-up’ style shows- where I would wander around a dinner or event, giving short performances to small groups of people. In some cases, my set would consist of a series of coin tricks. For example, I might take an napkin from the table, crumple it into small ball, and appear to transform it into a silver dollar. “Do you know the trick?” I’d ask the audience while appearing to hand the coin to nearby spectator for them to examine. I would quickly follow up with “The trick is that this isn’t even real.” At the same time, I would cause the coin to appear to vanish. This would lead to a brief routine where the coin would repeatedly reappear and vanish in various apparently impossible ways. At the conclusion of the routine, I would openly place the coin in my pocket, thank the audience for their time, and begin to move away. Sometimes an audience member would ask to see one more thing before I left. For my ‘encore’ I would sometimes simply reach my hand into the pocket where I had previously placed the coin. I would leave the coin in the pocket, but I would rummage around a bit and take out my empty held in such a way that it might be holding a coin occluded behind my finger-tips. I would hold the empty hand out in front of me and instruct the audience to “Watch closely.” I’d add, “You probably see it this time.” Then I would slowly and deliberately go through the pantomime of making the coin vanish. My actions were choreographed to be similar to the actions the audience had previously seen when I had actually been holding and subsequently concealing a coin in my hands. But, this last time, there was never a coin to begin with. The absence of the coin allowed me to end the vanish ‘cleanly’ in that, after the vanish had ‘happened,’ I could clearly show the spectators that both of my hands were completely empty. If they bought into the idea that I had been holding a coin in my hands, then there was no logical explanation for how and where the metal disc had disappeared to. Ironically, for many years I thought the effect just described was a textbook version of what Bobo (1952) had referred to as a ‘Bluff Vanish.’ When, in fact, it turns out that my memory of the trick had been distorted over the years in that I had actually excised significant parts of the original method. The first version of the Phantom Vanish Magic Trick, described in chapter 5, was derived from this routine.

This concept first appeared in print as “The Pretense Coin Vanish” in a small, independently published, magician’s magazine (Shephard, 1946).

The Pretense Coin Vanish, by Steve Shepard.

Have in the right coat pocket a number of coins. Reach in and take out several with right hand Hold them in palm and show. Pretend to take one and close the right hand, dropping the remaining coins into pocket. Pretend to be holding a coin in left hand. Snap fingers and show coin vanished. Do again use a different method. Hold out the handful of coins and start to reach for one. When ready to remove a coin, push it under a larger coin. Execute the same way as before.

The idea subsequently appeared under the name of “The Bluff Vanish” in Bobo’s *Modern Coin Magic* (1952).

The Bluff Vanish

“All that you need to perform this little miracle is handful of change and a lot of nerve

Effect: *The wonder worker takes a handful of change from his pocket and removes one coin. The remaining coins are returned to the pocket. The single coin is then caused to vanish in a mysterious manner. The secret of this effect depends entirely on your ability as a magician to bluff your way through. Let us suppose you have thoroughly baffled your spectators with some clever close-up chicanery. You have convinced them that miracles can*

happen and they're ready to believe anything. Now is the time to spring this vanish.

Method: *If you carry your loose change in your left trousers pocket you will always be ready to work this little effect; otherwise prepare for it beforehand by placing a few small coins in that pocket. Remove the coins with the left hand and show them. Move the coins about with the right fingers as if searching for a particular one. Say something about needing a coin for your next trick. Suddenly remark, "Oh this penny (or dime or nickel) will be alright." Pretend to remove one of the coins with the first and second fingers and thumb of the right hand. Hold the first two finger tips and thumb together as if they actually held a coin. The left hand drops the rest of the coins into the left trousers pocket. Go through the motions of placing the non-existent coin in the left hand. Show the right hand empty. After a bit of by-play open the left hand and show it empty. Performed at the right moment this vanish is as startling as the more complicated ones, I have used for years and can vouch for it's effectiveness."*

Appendix H: Participant Instructions from Chp. 5

Thank you for your interest in this study. Please take a moment to read through the following information.

We are investigating how people perceive sleight-of-hand illusions, and have invited you to take part as a member of the general public. This study will consist of watching a series of short videos and completing a simple electronic questionnaire. The experiment should take about 10 minutes to complete. There are no risks associated with your participation in this study.

For this experiment you will be asked to watch a series of short video clips.

Please Note: We are interested in your first impressions so each clip can only be played ONCE. You will NOT be able go back and replay any video once it has finished.

You control when each video starts.

Before every video, you will see a blank screen.

Press the space bar when you are ready to watch. The video will begin after a 3 second countdown (each of the videos will be less than 30 seconds long).

After each video finishes, you will be asked 4 questions about what you just watched. The first question will require a written response. For the next 3 questions, you will be asked to provide ratings.

You will now have the opportunity to complete a practice trial. This practice trial is in an identical format to the experimental trials.

When you are ready to begin, click the 'start practice' button below.

If you would like to see the instructions and do the practice again, click the 'Instructions' button below.

When you're ready to start just click the 'start study' button below

[Clicking 'start practice trial' would play a short video of a card trick, followed by slides that showed all the questions on the spectators experience questionnaire, during this practice period participant responses were not recorded, and responding to the questions was not necessary for them to proceed. After the clicked next on the final practice question. Clicking 'start study' would cause the following phrase to appear on screen.]

Press SPACE to begin

[The experiment video would play after the participants had pressed the space bar on their keyboard. After the video concluded, participants were presented with the following question:]

Please write a description of what was shown in the video. Do your best to describe specific actions and events in the order that they occurred.

[Participants needed to type something into the box before they could move on to the next slide]

How surprising did you find the events shown in this video? Please use your mouse to indicate your response on the slider below.

[Participants needed to click somewhere on the visual analog scale, see Appendix F, before they could proceed]

To what extent did the events shown in this video seem to you to be physically impossible? Please use your mouse to indicate your response on the slider below.

[Participants needed to click somewhere on the visual analog scale see Appendix F, before they could proceed]

How magical did you find the events shown in this video? Please use your mouse to indicate your response on the slider below.

[Participants needed to click somewhere on the visual analog scale, see Appendix F, before they could proceed. The first four times they answered this question, the ‘next’ button would cause another video to begin playing]

One last question: In general, how interesting do you consider magic tricks to be? Please use your mouse to indicate your response on the slider below.

[Participants needed to click somewhere on the visual analog scale see Appendix F, before they could proceed to the final slide]

Dear Participant,

Thank you very much for taking the time to be part of our study. Please feel free to contact the researchers on the email addresses listed below should you have any questions, or if you wish to register interest in participating in further studies.

We would very kindly ask that you do not tell anyone the specific details of this study, as this will confound our results if that person(s) also chooses to participate in this study.

Your help is very much appreciated.

[This slide was accompanied by a pop-up window that allowed participants to collect their payment]

Participant Instructions from Chp. 5
No Misinformation Condition (Condition 1)

Thank you for your interest in this study. Please take a moment to read through the following information.

We are investigating how people perceive sleight-of-hand illusions, and have invited you to take part as a member of the general public. This study will consist of watching a series of short videos and completing a simple electronic questionnaire. The experiment should take about 10 minutes to complete. There are no risks associated with your participation in this study.

For this experiment you will be asked to watch a short video clip.

Please Note: We are interested in your first impressions so the clip can only be played ONCE. You will NOT be able go back and replay the video once it has finished.

You control when the video starts.

Before the video, you will see a blank screen.

Press the space bar when you are ready to watch. The video will begin after a 3 second countdown.

The video finishes, you will be asked 4 questions about what you just watched. The first question will require a written response. For the next 3 questions, you will be asked to provide ratings.

You will now have the opportunity to complete a practice trial. This practice trial is in an identical format to the experimental trials.

When you are ready to begin, click the 'start practice' button below.

If you would like to see the instructions and do the practice again, click the 'Instructions' button below.

When you're ready to start just click the 'start study' button below

[Clicking 'start practice trial' would play a short video of a card trick, followed by slides that showed all the questions on the spectators' experience questionnaire, during this practice period participant responses were not recorded, and responding to the questions was not necessary for them to proceed. After the clicked next on the final practice question. Clicking 'start study' would cause the following phrase to appear on screen.]

Press SPACE to begin

[The experiment video would play after the participants had pressed the space bar on their keyboard. After the video concluded, participants were presented with the following question:]

Please write a description of what was shown in the video. Do your best to describe specific actions and events in the order that they occurred.

[Participants needed to type something into the box before they could move on to the next slide]

How surprising did you find the events shown in this video? Please use your mouse to indicate your response on the slider below.

[Participants needed to click somewhere on the visual analog scale, see Appendix F, before they could proceed]

To what extent did the events shown in this video seem to you to be physically impossible? Please use your mouse to indicate your response on the slider below.

[Participants needed to click somewhere on the visual analog scale see Appendix F, before they could proceed]

How magical did you find the events shown in this video? Please use your mouse to indicate your response on the slider below.

[Participants needed to click somewhere on the visual analog scale, see Appendix F, before they could proceed. The first four times they answered this question, the ‘next’ button would cause another video to begin playing]

One last question: In general, how interesting do you consider magic tricks to be? Please use your mouse to indicate your response on the slider below.

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We would very kindly ask that you do not tell anyone the specific details of this study, as this will confound our results if that person(s) also chooses to participate in this study.

Your help is very much appreciated.

[This slide was accompanied by a pop-up window that allowed participants to collect their payment]

Appendix I: Neurological and Philosophical Implications of Eating a Crayon



One outstanding question about magic relates exactly what spectators experience when they witness magic tricks, variously described as a feeling of ‘awe’ or ‘wonder,’ the ‘illusion of impossibility,’ the ‘moment of astonishment.’ This magical experience is a moment when the spectator seems to experience something that they know cannot possibly be real.

On one hand, one might argue that spectators who witness a magic trick are simply experiencing a strong expectation violation, they are anticipating A but are confronted with B. But, on the other hand, perhaps there is something particularly special about magic. Maybe violations of our deeply held beliefs about the nature of reality are mechanistically distinct from other kinds of surprise.

One tangential point of interest relates to the non-magic control video in the crayon condition (Video 3, Condition 5). This video depicted the magician removing a crayon from the cup, and then slowly placing it into his mouth and chewing it, before making an ‘end of trick’ gesture. This was what genuinely happened, although

immediately after the video cut I spat out the wax. The experience was unpleasant, and the video unfortunately required two takes, because I had misaligned the camera on my first filming attempt. This particular video is one of the most theoretically interesting because it was the only non-magical video that matched with a corresponding magical video in terms of participants' surprise ratings. Participants rated Video 3, Condition 5 to be significantly less magical and less impossible than Video 1, Condition 5 (the vanishing of the crayon), but they did *not* rate it as being significantly less surprising. In other words, the depiction of eating the crayon was thought to be as surprising as the magical/impossible depiction of a crayon apparently vanishing from the magician's hands. This raises interesting questions about the phenomenological experience of watching magic tricks. The fact that stimuli can be created that are matched for subjective 'surprising-ness' while differing in apparent 'magical-ness'/'impossible-ness' raises the possibility that a neuro-imaging experiment might be developed where such stimuli are explicitly contrasted to reveal the neurophysiological similarities and differences between experiencing something that is apparently impossible versus something that is merely unexpected. Maybe magical experiences only differ from surprise on the basis of magnitude or perhaps there the experiences involve different neurological mechanisms. Either result would be theoretically interesting and might have implications for our neuropsychiatric understanding of aberrant perceptual experiences.