CONSTRUCTIVISM, CURIOSITY, AND METACOGNITIVE BIAS IN THE AGE OF GOOGLE

by

Matthew Daniel Moore

Liberty University

A Dissertation Presented in Partial Fulfillment

Of the Requirements for the Degree

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ABSTRACT

The purpose of this experimental, posttest-only control-group study was to determine if there are differences in levels of metacognitive bias between those who do and do not use Google on a practice activity prior to the administration of a general knowledge test, when controlling for epistemic curiosity. The study seeks to help fill the gap in the literature by examining differences in metacognitive bias across not only the experimental variable of Google access, but also by participant variables, providing a more thorough understanding of how differences in individuals may moderate the relationship between Google use and bias. A sample of 140 participants was selected randomly from a population comprised of the student body of two public high schools, both in the state of South Carolina. The study found that Google access resulted in significantly greater metacognitive bias, even after controlling for epistemic curiosity, indicating that Google, and the internet at large, represent a potentially significant pedagogical threat to the prior knowledge and metacognitive accuracy needed to learn. These results highlight the need for further research into instructional practices which utilize internet search tools, curiosity as a state versus curiosity as a trait, and the societal ramifications of unchecked cognitive offloading.

Keywords: Epistemic Curiosity, Cognitive Offloading, Metacognitive Bias, Metacognitive Monitoring, Metacognitive Accuracy

Dedication

This study is dedicated to my wife, Alissa Moore, who, for 20 years, has consistently supported me and believed in me, often more than I believed in myself. Without her love and encouragement, none of this work would have been possible. It is my hope that she knows that whatever I accomplish, whether it be personally, academically, or professionally, is done to make her proud and to honor the love and commitment she has provided without hesitation my entire adult life.

Acknowledgments

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List of Abbreviations

Analysis of Covariance (ANCOVA)

Analysis of Variance (ANOVA)

Functional Magnetic Resonance Imaging (fMRI)

General Linear Model (GLM)

Statistical Package for Social Sciences (SPSS)

CHAPTER ONE: INTRODUCTION

Overview

Chapter One will provide an introductory overview of Google's purported impacts on cognition and learning, as well as related background information on epistemic curiosity and metacognitive bias, highlighting potential real-world connections between these concepts, and contextualized within the theoretical framework of constructivism. The problem statement will include gaps in extant literature and proposed areas of future research. The purpose statement will identify the research goal of the current study, which will be followed by the research questions and definitions of important concepts.

Background

The internet and its attendant search engines represent perhaps the most significant advance in informational technology since the advent of the printing press (Bourdon, 2018). The overwhelming majority of Americans have the internet's seemingly boundless reservoir of information at their fingertips, with nearly 97% of Americans maintaining access to broadband internet (Federal Communications Commission, 2019). Further accelerating the penetration of the internet's reach into Americans' daily lives is the ubiquity of smartphone adoption; 85% of Americans own a smartphone (Pew Research Center, 2021). As internet access and adoption continue their meteoric rise, the use of search engines has become a hallmark of daily life. Of these search engines, Google is predominant, accounting for nearly 92% of market share (*Search Engine Market Share Worldwide*, n.d.).

Such unrivaled popularity allows Google to function as a gatekeeper of the world's knowledge, with some arguing that Google essentially serves a quasi-governmental role (Badouard et al., 2016). The progression of internet adoption and the popularity of Google have led, predictably, to both opportunities and challenges within the domain of education. While Google provides virtually instant access to an ever-expanding trove of data, that same efficiency and convenience represents a potential risk to the cognitive mechanisms largely responsible for new learning. The nearly limitless reservoir of instantly accessible knowledge found online makes Google not only a powerful informational tool, but also the catalyst for novel cognitive threats; the combination of Google's seemingly infinite collection of information and its rapid transmission of that information can "blur the boundaries between internal knowledge—stored in personal memory—and external knowledge—found online" (Ward, 2021, p. 1). Google has, thanks to its usefulness and ease, become an entrenched staple of daily life, with *just Google it* an increasingly common epistemological mantra, especially for students (Bhatt & MacKenzie, 2019).

Humans have long utilized external memory—the use of external cues from the outside environment—as a supplement to their internal memories (Dunn et al., 2021). This strategy, known as *cognitive offloading*, is utilized to relieve cognitive demands on other memory systems, such as working memory (Risko & Gilbert, 2016). Cognitive offloading has historically taken the form of notes, books, mnemonic devices, and even other people. What differentiates Google from these more traditional external memory aids is the speed, access, and ubiquity of information associated with a Google search. Whereas accessing information via traditional external memory stores face restrictions of effort, time, access, or location, Google is comparatively unencumbered by such limitations (Ståhl, 2019). As such, Google is fundamentally different than prior external memory aids, leveraging cognitive biases towards speed, fluency, and ease (Ward, 2013). Google thus may have the potential to marshal humans' hardwired association of speed with internal knowledge in problematic ways. Recent literature indicates that individuals who utilize internet searches not only store the newly encountered material worse than non-internet learners but are also significantly overconfident in their capacity to recall such information on their own in the future—a phenomenon termed *metacognitive bias* (Dunn et al., 2021; Fisher et al., 2021; Fisher et al., 2015). Subsequently, there appears to be evidence that the use of Google elicits a false confidence in one's internal knowledge of the searched material, presenting a potential roadblock to new learning.

An integral component of such learning is epistemic curiosity, which is the "desire for knowledge that motivates individuals to learn new ideas, eliminate information-gaps, and solve intellectual problems" (Litman, 2012, p. 1). Distilled to its simplest form, epistemic curiosity represents the degree to which an individual values learning new material. It is important to note a frequent dichotomy utilized in analyses of curiosity: the distinction between state and trait curiosity. State curiosity refers to the temporary, situational drive to fill a knowledge gap, while trait curiosity refers to the intrinsic and continuing drive to explore and learn (Kashdan et al., 2020; Silvia 2007).

If, in fact, Google use provides a false sense of knowledge, state curiosity may be negatively impacted by the use of such tools. Conversely, it is possible that individuals who evince greater levels of trait epistemic curiosity may be less vulnerable to the metacognitive biases associated with Google reliance. It may even be possible that a modicum of bias actually increases exploratory behavior, when the "feeling of knowing"—the subjective perception that an individual experiences when they are confident that they have stored information but cannot at the time recall it—increases curiosity (Brooks et al., 2021, p. 4).

Historical Overview

Concern regarding the medium of information transmission and consumption has existed for millennia. Socrates bemoaned the written word as inferior to oral speech and a cause of collective forgetfulness (Woolf, 1999). Clark and Chalmers (1998) were one of the first to explore the potential benefits and challenges of screen-based technologies as part of an extended mind. At least as early as 2000, academics expressed concern about the potentially chaotic impact of the internet on communication—particularly formal argument—as well the risk the internet presents in creating confusion between the transmission of knowledge and the actual encoding of knowledge (Barker, 2000; Steinmueller, 2000). Nicholas Carr (2008, 2010) argued that the Google ecosystem alters our cognition by prioritizing efficient but superficial intellectual tasks over slower but deeper ones, expressing his expectation that future studies would confirm such suspicions.

Sparrow et al.'s (2011) study on Google as a transactive memory partner found that individuals appear to intuitively seek the internet for answers when faced with difficult questions, and when assessed on information earlier accessed via web searches, were significantly more likely to be able to recall where they accessed the information rather than the information itself. Adrian Ward (2013) was one of the first to hypothesize that the internet leverages humans' inherent cognitive architecture in novel ways, blurring the boundary of where internal knowledge ends and external knowledge begins. Dunn et al., (2021) and von Hoyer et al. (2022) both reported that internet searches appeared to be associated with overconfidence, even for ultimately incorrect answers.

Society-at-Large

Hypothesized internet search-induced metacognitive bias has myriad potential impacts on multiple facets of society (Favero & Candellieri, 2017; Firth et al., 2019; Marsh & Rajaram, 2019). Metacognitive bias is an integral element of the Dunning-Kruger effect, the phenomenon in which self-assessed knowledge and skill are negatively correlated to actual knowledge (Kruger & Dunning, 1999). Similarly, metacognitive bias appears to coincide with source misattribution. Ward (2021) found that individuals who use Google are significantly more likely to misattribute the information they found in their search for their own knowledge, hypothesizing that the speed and intuitive nature of Google actually exceeds internal memory recall under many conditions. This becomes heightened importance in today's hyper-partisan political milieu, since source misattribution is associated with the promotion of fake news, and subsequently, partisanship (Levy, 2017). Further, if individuals who have a deficit of prior knowledge are both unaware of their own ignorance and more likely to be Google-reliant, it can be hypothesized that their Google use may exacerbate their knowledge misattribution and metacognitive bias, leading to further deficits.

Theoretical or Conceptual Background

Arguably the most foundational tenet of constructivism—a predominant epistemological framework in modern public education—is that "the most important single factor influencing learning is what the learner already knows" (Ausubel, 1968, p. vi.). Constructivism falls within the broad, eclectic collection of theories of cognitivism (Eggen & Kauchak, 2016), but is differentiated by the fact that it posits that prior knowledge and prior experiences are prerequisites for new learning, since new cognitive material must attach to previous memory structures (Schunk, 2020). Constructivism itself has multiple representations and points of emphasis, from von Glaserfeld's radical constructivism, which poses that not only is knowledge constructed developmentally and entirely within the context of the individual's body of personal experience, eschewing notions of absolute truth (Walshe, 2020), to Ausubel's framework of subsumption, which often seems to approach knowledge as being both constructed and acquired.

Ausubel, through his Theory of Subsumption, elaborated on the importance of prior knowledge by describing the process by which discrete units of external information are subsumed under, attached to, and ultimately absorbed by, more inclusive cognitive structures. Over the course of time, new information loses much of its detail, while the core knowledge or "memorial residue" remains as both a "manipulable" resource for problem-solving and an anchor for the learning of future material (Ausubel, 1962, pp. 217-218). In this way, knowledge is not only a byproduct or evidence of learning, but rather an active and important resource for future learning. If the accumulation of prior learning is itself subsumed as schema, collective deficits in prior knowledge necessarily entail deficient schemata. Importantly, prior knowledge also informs and shapes what students direct their attention to; that attention subsequently shapes what they learn (Çakır, 2008).

Piaget (1960), a proponent of strong or radical constructivism, believed that knowledge is strictly constructed, not acquired, as in Ausubel's model (1962). Piaget also differed from Ausubel in terms of the nature of cognitive structures; whereas Ausubel felt that new cognitive material must be subsumed under existing structures, Piaget described the process of accommodation, wherein new schemata can be constructed. Because both largely viewed learning as individualized processes, both differed from the famed social constructivist, Lev Vygostsky (1978), who positioned learning as a social enterprise, and who famously originated the concept of the zone of proximal learning—the intellectual space between what a learner can already do and what they cannot do, and bridged by what can be learned with the help of a more knowledgeable other. Regardless of such distinctions, all varieties of constructivism reject behaviorism's distillation of knowledge as external information transmitted to the internal (Derry, 1996). Meanwhile, the explosive rise in the popularity of and reliance upon Google has created a context in which *just Google it* is a fundamental part of many Americans' cognitive lives, and in which students seem to utilize Google less as an exploratory tool and more as an external memory source. Such a mindset essentially shifts students' cognitive paradigm from *how do I learn something* to *where do I find it*.

Problem Statement

While there is a growing body of research on epistemic curiosity and Google's impact on cognition (Firth et al., 2019; Fisher et al., 2021; Fisher et al., 2015; von Hoyer et al., 2022; Ward, 2021), there is a need for further research regarding causative, predictive, or moderating variables related to such bias. Dunn et al. (2021) and Firth et al. (2019) indicated a need to extend research on metacognition to include how individual differences in populations may impact internet-related impacts on cognition. Risko and Gilbert (2016) and Storm et al. (2016) suggested that future research should be directed at better understanding the processes of offloading cognitive tasks to external sources, with an emphasis on how such offloading impacts humans' natural cognitive abilities. Further, many of the studies specifically designed to examine the interaction between Google and metacognition utilize Amazon's Mechanical Turk (Dunn et al., 2021; Ward, 2021) or university volunteers (Pieschl, 2019; Stone & Storm, 2021; Storm et al., 2016) for sampling largely preventing participation by adolescents.

Loewenstein (1994) described the need to better understand the strength and direction of the relationship between metacognitive judgments and curiosity. It could be that an individual who believes they know very little about a topic or task maintains the greatest curiosity, since they perceive a greater knowledge gap; however, it could also be that the individual who self-assesses a high degree of knowledge subsequently perceives more lines of inquiry that must be researched. Kashdan et al. (2020) indicated the need for future research to untangle the nature and malleability of curiosity, with an emphasis on discovering what fosters and what hinders it. Pieschl (2019) suggested further research into the prevalence of internet-aided overconfidence, as well as ways to mitigate it. The problem, then, is that the literature has not yet adequately examined whether or not Google influences levels of metacognitive bias, and further, if epistemic curiosity, as an individual trait, serves any kind of moderating function in such a proposed relationship.

Purpose Statement

The purpose of this experimental posttest-only control-group study was to determine if there are differences in levels of metacognitive bias between those who do and do not use Google on a practice activity prior to the administration of a general knowledge test, when controlling for epistemic curiosity. The independent variable in this study was Google access, while the covariate is epistemic curiosity, the desire to learn new material in order to solve problems and eliminate gaps in understanding (Litman, 2012). Google access is comprised of two levels, participants allowed Google access and participants without. The dependent variable was metacognitive bias or overconfidence, which is the calibration of self-assessed, predicted knowledge and actual understanding, indexed as participants' actual performance on a general knowledge assessment minus their predicted performance (Dunlosky & Metcalfe, 2009; Dunn et al., 2009). A positive value indicates metacognitive bias in the form of overconfidence, while a negative value indicates relative underconfidence.

Significance of the Study

The study sought to help fill the gap in the literature by examining differences in metacognitive bias across not only the experimental variable of Google access, but also by participant variables, providing a more thorough understanding of how differences in individuals may moderate the relationship between Google use and bias. Researchers have recently indicated the need to examine the impact of distributed metacognition, such as the use of Google, on metacognitive bias from different demographic subgroups (Dunn et al., 2021). Similarly, Fisher et al. (2021) called for future research into the extent with which individual-level differences can predict metacognitive behaviors. Flanagin and Lew (2022) called for further research into the phenomenon of misattributing external knowledge as internal knowledge. Tang and Salmela-Aro (2021) suggested future studies on the potential of epistemic curiosity and other individual traits as moderators of performance.

If data analysis suggests that Google use is associated with greater metacognitive bias, but those effects are mitigated or eliminated when controlling for epistemic curiosity, strong evidence of the need for future research into trait curiosity's relationship with metacognitive accuracy would be provided, as well as the determinants and development of trait epistemic curiosity. If differences in bias remain after controlling for curiosity, even with a demonstrated linear relationship between epistemic curiosity and metacognitive bias, an even greater influence of Google on metacognitive bias would be suggested. Further, such a result would potentially favor a predominantly state model of curiosity, wherein curiosity is considered less of an intrinsic trait and more of a malleable state of perception, with the potential for drastic manipulation by external variables. In other words, if preliminary data screening and assumption testing present a generally linear negative relationship between epistemic curiosity and metacognitive bias, yet controlling for curiosity does not significantly decrease bias, it may be possible to infer that the epistemic curiosity score collected prior to testing is not fixed and was potentially influenced by way of the experimental treatment. Because curiosity is largely driven by a subject's knowledge of one's own information gaps (Loewenstein, 1994; Singh & Manjaly, 2021), the author of the current study hypothesized a generally linear, negative relationship between epistemic curiosity and metacognitive bias.

This study is directly relevant to education, as the internet and internet-connected devices further saturate school systems, and students report not even being able to imagine life without the internet (Anderson & Jiang, 2018). Constructivism, with its emphasis on prior knowledge and experience as a foundation for new learning, brings the risks associated with metacognitive bias into clear focus. If Google reliance fosters an environment in which students increasingly have inaccurate judgments of their prior knowledge, this may lead to decreased student valuations of internal knowledge. Such a feedback loop would be self-perpetuating, resulting in incrementally greater deficits in prior knowledge, subsequently making new learning more difficult. In such a scenario, deficits in schemata would be greater in higher level courses or grades, directly impacting college and career readiness.

Research Question(s)

RQ: Is there a difference in metacognitive bias scores among high school students who are allowed to utilize Google on a practice activity prior to a general knowledge assessment and those who are not, when controlling for epistemic curiosity?

Definitions

1. *Cognitive Offloading* – The process of using physical or external mechanisms to reduce cognitive demand (Risko & Gilbert, 2016).

2. *Constructivism* – An epistemological and educational framework which posits that knowledge is constructed internally, via the individual’s incorporation of external information into or around pre-existing cognitive structures (Schunk, 2020).
3. *Epistemic Curiosity* – An individual’s intrinsic desire to learn new material in order to solve problems and eliminate gaps in their own understanding (Litman, 2012).
4. *Feeling-of-Knowing* – An individual’s self-perceived ability to recall specific information in the future, despite the initial inability to recall it from memory at present (Ferguson, et al., 2015).
5. *Metacognitive bias*- An individual’s overconfidence or underconfidence on a cognitive task, measured by predicted or judged performance minus actual performance (Dunn, et al., 2021).
6. *Source misattribution* – The act of erroneously identifying information obtained from external sources as one’s own internal knowledge (Ward, 2021).
7. *State curiosity*- The fluid, temporary desire for knowledge acquisition which varies over time and is attributable to external stimuli (Kashdan et al., 2020; Silvia 2007).
8. *Trait curiosity*- The intrinsic, stable personality characteristic describing one’s innate desire to acquire new knowledge (Kashdan et al., 2020; Silvia 2007).

CHAPTER TWO: LITERATURE REVIEW

Overview

The purpose of this quantitative, posttest-only control-group study is to determine if there is a difference in levels of metacognitive bias, or overconfidence, between high school students who are granted access to Google on a practice assessment and those who are not, after controlling for individual epistemic curiosity. A systematic review of the literature was conducted to examine hypothesized multi-directional, interconnected relationships between students' epistemic curiosity, Google overreliance, and metacognitive bias. This chapter will thus review the current literature on each of these topics both independently and where they overlap, or where it suggests causal relationships. In the first section, the relevant psychological theories, which provide the most comprehensive foundation for examining connections between these variables, will be discussed. This will be followed by a synthesis of recent literature on metacognitive bias and epistemic curiosity, leading to a review of literature which addresses the impact of Google on learning and metacognition. Subsequently, a gap in the literature will be illustrated, evincing the need for the current study.

Theoretical Framework

There are subsequently numerous theoretical concerns regarding overreliance upon external memory sources, such as Google, and the metacognitive bias or overconfidence that appears to be elicited by such overreliance. External memory is a term used to describe the human phenomenon, present for millennia, in which humans store information outside of their own minds for later retrieval, in order to offload or lessen cognitive demand (Nestojko et al., 2013). Given that the purpose of the current study is to analyze the interaction between metacognitive monitoring of internal knowledge, epistemic beliefs, and web searches, the theoretical lens of constructivism will be utilized. From the constructivist perspective, if Google is consistently utilized as a proxy for the actual long-term encoding of information, a dangerously perpetual and self-reinforcing deficit in prior knowledge becomes a significant threat, which hypothetically manifests as metacognitive bias. Because learning theories and epistemologies under the umbrella of constructivism support the emphasis on existing knowledge as a prerequisite to acquiring or constructing new knowledge (Schunk, 2020), such theories serve as the most appropriate lens through which to view this threat.

Proponents of constructivism, which is arguably the predominant and most influential learning and epistemological theory in modern public education, posit that students construct knowledge instead of passively receiving it (Schunk, 2020). Comprised of ultimately structuralist theories, constructivism emphasizes the role that prior knowledge plays in the learning process, since new information is anchored into existing cognitive structures, while the core knowledge or memorial residue remains as both a resource for problem-solving and an anchor for the learning of future material (Ausubel, 1962). Through this constructivist lens, the single most critical variable in the experience of a learner is what he or she already knows, as discrete units of external information are incorporated by existing schemata or utilized via accommodation in the creation of new structures, allowing for the learner to make connections between known and newly learned materials (Piaget, 1960). In this way, knowledge is not only a byproduct or evidence of learning, but rather an active and important resource for learning. If the accumulation of prior learning is itself subsumed as schema, collective deficits in prior knowledge necessarily entail deficient schemata. Because new cognitive material not anchored into existing structures will be much more vulnerable to being forgotten, and subsequently unable to be utilized in future learning (Ausubel, 1962), constructivism subsequently provides a useful lens through which to critique any informational technology which truncates, interferes with, or interrupts the formation of internal knowledge.

On May 7th, 2012, Dr. Dimitri Kanevsky, a researcher in the Speech and Language Algorithms Department at the IBM T.J. Watson Research center, stood in the White House and boldly proclaimed:

> Technology is the great equalizer that can dramatically improve the quality of a person's life through the click of a mouse button, (….) constantly evolving to remove barriers that emerge due to a person's social characteristics, geographic location, physical or sensory abilities (National Archives and Records Administration).

Kanevsky's optimism is not unfounded, nor is it novel. Silicon Valley has generally assumed a posture of grandiose, arguably domineering paternalism since the spectacular rise of the internet, proffering technology as the cure to all of society's ailments (Vaidhyanathan, 2018). This unyielding, idealistic commitment to technology as a kind of societal savior has been termed "techno-fundamentalism" by media scholar Siva Vaidhyanathan, who defines it as an extreme form of "technological optimism" which "assumes not only the means and will to triumph over adversity through gadgets and schemes, but the sense that invention is the best of all possible methods of confronting problems" (2006, p. 556). Such soaring, starry-eyed rhetoric has inevitably made its way into the study of human learning and psychology, with some researchers suggesting a type of extended or shared mind (Smart, 2012; Staley, 2014).

In such a model, the internet and its connected devices, as well as the accumulation of web-stored information accessed by such devices, become essentially part and parcel of the mechanistic process of human cognition (Smart, 2017). This hypothesis, and those like it, take Information Processing Theory's central analogy of the brain as a computer (Schunk, 2020), and actualize it in practice, presenting human minds as hubs within a vast network, interacting with external memory partners which store information for retrieval. In such a framework knowing *what* truly is secondary to knowing *where*. There is, however, reason to be skeptical regarding the prospect of technology, particularly the internet, serving as the great panacea of society, specifically in the world of education. Such skepticism largely centers around the role of prior knowledge, and specifically how prior knowledge is leveraged for the creation or acquiring of new knowledge. Osiurak et al. (2018) found that, in contrast to the techno-fundamentalist proposition that technology can and does close or eliminate gaps due to individual differences, technological tools appear to extend, not eliminate, differences in cognitive skills, because individuals are limited by their own initial understanding or existing knowledge base. Osiurak et al.'s findings regarding the limited utility of technological tools in closing such gaps only scratch the surface of the educational dilemmas that arise from inadequate prior knowledge.

For instance, when students lack the prior knowledge needed for new learning, they may fail to engage in more meaningful cognitive efforts, such as deep information processing or problem solving (Ferguson et al., 2015; Loh & Kanai, 2016; Marsh & Rajaram, 2019; Risko et al., 2016, von Hoyer et al., 2022). This could hypothetically lead to greater deficits in knowledge and further reliance on Google. The cycle would then continue and theoretically escalate, since a lack of relevant prior knowledge appears to be a significant contributor to low performers' inability to accurately assess their own performance (Mihalca et al., 2017; Nguyen, 2019; van Loon et al., 2013). Such metacognitive struggles, in turn, may lead to myriad learning obstacles, including underachievement (Dunlosky & Rawson, 2012), worse metacognitive control (Destan & Roebers, 2015), and greater susceptibility to inaccurate information (Salovich & Rapp, 2021). Deficits in prior knowledge could thus have far-ranging and profound educational impacts, since an individual's body of background knowledge is known to play a crucial and fundamental role in memory encoding, consolidation, and retrieval (Fernández & Morris, 2018). It is unsurprising, then, that ample evidence suggests constructivist pedagogical techniques are effective. A 2017 meta-analysis of 38 quantitative studies on the 5E learning model, a constructivist pedagogical framework, revealed students within such a model evinced significantly greater achievement than students in control groups (Çakır, 2017). Evidence for the efficacy of constructivist teaching techniques, in both traditional and online learning environments, is abundant (Ayaz & Sekerci, 2015; Funa & Talaue, 2021). The constructivist emphasis on prior knowledge and experience brings into sharp focus the vital role of encoded information in the learning process.

A 2021 meta-analysis of 23 studies exploring the relationship between prior knowledge and reading comprehension revealed that sufficient background knowledge plays a significant compensatory role for readers of lower skill levels, allowing them to outperform on comprehension measures relative to their respective reading fluency, and further, that integrating a textbase, which is the body of new words recently encountered in a text, becomes difficult to the point of overloading working memory without such prior knowledge (Smith et al.). Literature also suggests that the benefits of prior knowledge are clearly evident in writing or other cognitively demanding tasks (Simonsmeier et al., 2021). Çakır's (2008) review of constructivist approaches to scientific education similarly evinced that students' epistemological beliefs shape their views about learning, making the adoption of a constructivist epistemology crucial to new learning. Cakir strikes a decidedly constructivist tone by concluding that students' prior knowledge and experiences largely determine what information will be selected for attention, and subsequently, what information they will learn. The selection of attention is predominantly an interaction between what the learner knows and what the learner is as-yet unable to integrate into his current schema, known in constructivist literature as disequilibrium (Smith et al., 2021). Prior knowledge is therefore a crucial variable in the productive struggle or desirable difficulty encountered with learning new cognitive material (Bjork & Bjork, 2020). Because depth of encoding and learning appear to have a roughly positive linear relationship with task difficulty (Hodges & Williams, 2019), instructional designs which intentionally elicit disequilibrium and invite productive struggle have been found to be effective, but are severely hampered by significant gaps in prior knowledge, since there is an insufficient schema into which the learner may struggle to place the new material (Pan & Sana, 2021).

Given the efficacy of constructivist practices, the tenets of prior knowledge and social learning gain even more relevance within the context of the inexorable spread of online learning modalities and digital instructional technologies (Agopian, 2022; Cross, 2021). Online instructional strategies that utilize constructivist frameworks are not only more positively received by learners, but also appear to be more effective (Funa & Talaue, 2021; Liaw et al., 2019). Student perceptions of constructive learning environments have been associated with greater use of metacognitive self-regulation strategies, which themselves are predictors of increased critical thinking (Dökmecioğlu et al., 2020). Given constructivism's priorities of rigor, prior knowledge, and social learning, there may thus be reason to look upon Google as a pedagogical tool with a degree of trepidation. From the social constructivist perspective, Google's use as a learning partner may be problematic, since learning is seen as a social, and largely verbal, enterprise; learning occurs via the zone of proximal development through the aid of a more knowledgeable other (Vygotsky, 1978). It is worth considering if the internet has replaced, or is in the process of filling, the role of the more knowledgeable other.

Within the social constructivist paradigm, the more complex a cognitive task is, and the less direct or simple the answer, the greater the need is for speech and social learning (Vygotsky, 1978). Most web users do not initiate an online search in order to gain information; instead, they engage with the platform in order to complete a task (Weinreich et al., 2008). Because of the advanced algorithmic nature of Google searches and the task-oriented purpose of related searches, there is cause to suspect that the speed and simplicity of the cognitive solutions therein do not require the elements necessary for constructive learning. Encoding knowledge entails more than the simple, temporary recitation of discrete facts; successful encoding, instead, occurs when the learner generates or constructs much of the to-be-remembered material, demonstrating superior recall and application relative to learners who receive read material passively (Benjamin, 2008). This passivity highlights one of the glaring novelties of Google relative to past external memory sources; Google places no responsibility on the user to retain important information for others to later use (Wegner, 2013).

Bloom's Taxonomy provides a supplemental lens through which to view web search-related epistemic confusion. As a hierarchical model, Bloom's Taxonomy demonstrates that foundational levels of knowing must be satisfied for a learner to progress to higher levels of understanding. Consider the importance of synthesis and originality in Bloom's seminal work from 1956:

> In synthesis, on the other hand, the student must draw upon elements from many sources and put these together into a structure or pattern not clearly there before. His efforts should yield a product--something that can be observed through one or more of the senses and which is clearly more than the materials he began to work with (p. 162).

The use of the web as external memory storage, however, often precludes the transformation of external information into internal knowledge, suggesting that a learner who uses Google as an extension of their own memory may be unlikely to encode the accessed information to allow for higher levels of understanding (Ståhl, 2019). This study will therefore frame analyses of Google within the context of impacts on internal knowledge and metacognition.

Related Literature

The internet and its ever-growing network of fast, mobile, intuitive devices represent arguably the most important and rapidly adopted informational technology in history (Bourdon, 2018; Firth et al., 2019; Soares & Storm, 2021; Stone & Storm, 2021). Google, for example, is a technological wonder, granting users access to a gigantic and unprecedented trove of information (Favero & Candellieri, 2017; Ferguson et al., 2015; Marsh & Rajaram, 2019; Ward, 2021). So ingrained into the 21st century student's workflow is the *just Google it* mantra, that many not only view the internet as their primary source of research (Turner & Rainie, 2020), but also cannot envision life without it, viewing the web as an extension of themselves (Anderson & Jiang, 2018; Bhatt & MacKenzie, 2019). Lurking beneath the mountains of accessible, catalogued, and monetized information, however, is the threat that students' increasing reliance on external memory partners, like Google, may have negative impacts on cognition and learning (Fisher et al., 2021; Saleh et al., 2011; Ståhl, 2019; Storm et al., 2016). Of particular importance is the role of prior knowledge, and the accurate metacognitive appraisal of it, in the learning process (Abdelrahman, 2020; Çakır, 2008; Cho et al., 2018; Risko et al., 2016; Smith et al., 2021; Woodward & Cho, 2020).

Epistemic Curiosity

One of this study's core points of emphasis regarding Google overreliance, from a constructivist perspective, is the impact such learned dependency could have on a student's valuation of knowledge itself, that is, curiosity. While the current study operationalizes epistemic curiosity as a stable personality trait, establishing a useful construct of precisely what the valuation is and how best to measure it is a crucial, if tedious, undertaking. Kashdan et al. (2020) established a nuanced, multi-dimensional model of curiosity, which is inclusive of traditional domains of curiosity and socially-driven curiosity constructs. Curiosity has been conceptualized both as an in-built personality trait, which is relatively stable and static, and a state, being a more temporary condition elicited by scenarios that trigger the desire to gain knowledge (Loewenstein, 1994; Murayama et al., 2019; Schutte & Malouff, 2019). Constructs of state curiosity frequently reference *tip-of-the-tongue* states, in which individuals are driven towards information-seeking behaviors via the subjective feeling that they know something but are unable to verbalize it (Litman, 2019; Litman et al., 2005; Metcalfe et al., 2017; Metcalfe et al., 2020). As such, state models of curiosity exclusively rely on individuals filling gaps in knowledge, wherein they are driven to seek information to end the discomfort associated with not knowing what one wants to know or thinks they already know (Kashdan et al., 2020; Litman & Jimerson, 2004; Markey & Loewenstein, 2014).

A potential stumbling block for tip-of-the-tongue states as a pedagogical tool is their temporary, easily satiated nature (Litman et al., 2005; Metcalfe et al., 2020). Because tip-of-the-tongue states are notoriously difficult to elicit and manipulate in experimental settings (Metcalfe et al., 2020), and because multiple researchers have called for exploring the interplay between genetic or personal traits and metacognition (Dunn et al., 2021; Firth et al., 2019; Risko &

Gilbert, 2016; Storm et al., 2016), the current study operationalizes epistemic curiosity as a personality trait.

Trait epistemic curiosity is best defined as the ingrained thirst for knowledge that motivates individuals to learn and is best understood as an inherent disposition or tendency towards knowledge-seeking (Litman, 2008; Litman, 2019; Litman & Jimerson, 2004; Litman & Spielberger, 2003). Litman and Spielberger's (2003) Epistemic Curiosity Scale entails 10 questionnaire items on a Likert-like response scale and can be used to discriminate between deprivation type curiosity, evoked by the need to eliminate the negative feelings brought by a lack of knowledge, and interest type curiosity, driven by the expected pleasurable experience of gaining new knowledge.

Learners with greater epistemic curiosity, particularly specific, intrinsic curiosity, demonstrate more creativity and problem-solving skills (Hardy et al., 2017), engage in deeper learning strategies with deeper learning motives (Binu et al., 2020), and evince better recall (Kang et al., 2008) than their less curious peers. Lee et al. (2022) demonstrated that students with greater interest-type epistemic curiosity evinced more emotional engagement with science content and subsequently, greater understanding, after the use of advanced organizers than less curious peers. According to Ruiz-Alfonso & León (2017), students' epistemic curiosity has also been positively correlated with optimal challenge, positive teacher feedback, and passion. Significantly, Ruiz-Alfonso and León found two of epistemic curiosity's strongest correlations in deep learning strategies and optimal challenge, with effect sizes of .722 and .604, respectively (2019). Since deep learning entails real-world relevance and applicability (Johnson, 2015), there appears evidence that rote tasks lacking such relevance are unlikely to elicit the curiosity and metacognitive monitoring processes that drives deeper knowledge acquisition (Kleitman & Narciss, 2019).

Individual differences in epistemic beliefs may play a crucial role in the ability of students to adapt to digital learning environments; students with naïve epistemic beliefs hold knowledge as the mere accumulation of facts, and the learning strategies they engage in reflect this assumption (Pieschl et al., 2013). Students with sophisticated epistemic beliefs hold that knowledge is a constructed network of facts, theories, and explanations, and as such are better able to adapt to a learning environment's contextual demands. Similarly, Cho & Woodward (2018) found that students with higher order epistemic processes, such as metacognitive monitoring, were significantly more successful in making connections and identifying emergent ideas within online texts than those with less sophisticated epistemic behaviors, who were more likely to interact with online texts at a more superficial level. Unsurprisingly, then, students with more sophisticated epistemic beliefs, that is, knowledge is complex, constructed, and interconnected, outperform students with more naïve epistemic beliefs (Mason et al., 2009). Metcalfe et al. (2020) found that greater levels of curiosity were associated with greater levels of agency and persistence, indicated by more curious individuals demonstrating a greater willingness to wait longer periods of time before requesting to be provided answers. It is unsurprising, then, that a catalyst for epistemic curiosity is prior knowledge, since such knowledge serves as a reference point for further exploration (Subasi, 2019). The tendencies of high epistemic curiosity move individuals towards deep thinking, perseverance, patience, and the eschewing of superficial solutions, which mesh neatly with the constructivist paradigm.

Metacognitive Bias

At its simplest, metacognitive bias is the overconfidence or under-confidence an individual experiences regarding their own understanding (Dunn et al., 2021). The measurement of metacognition, however, is an emergent field of inquiry, which requires a baseline understanding of a few similar, sometimes interchangeably, used terms and concepts. Discrimination, accuracy, and bias are all examples of calculations rendered from *metacognitive judgments* (Schraw, 2008). A *judgment of learning* is a self-assessment an individual makes regarding how well they have learned or understood new material (Dunlosky & Metcalfe, 2009). Similarly, learners can rate their subjective confidence on an upcoming assessment, a predictive judgment, or after they have finished the assessment, a postdictive judgment (Schraw, 2008). There are subsequently numerous metrics at the disposal of researchers, using judgments of learning or confidence ratings, and comparing them to actual assessment performance (Flemming & Lau, 2014).

The calculation of the accuracy of performance judgments can be performed at the local, individual-item level, or at the global, whole-assessment level (Rivers et al., 2019). Further, performance judgments can be provided prospectively, or before the administration of the assessment, or retrospectively, after the completion of the assessment. Analysis may take the form of item-level *discrimination*, the ability of an individual to correctly distinguish between confidence judgments for correct and incorrect answers, relative accuracy, the item-level relationship between confidence judgments and performance, and *bias*, which assesses the direction and magnitude of metacognitive judgments' relationship to task performance (Schraw, 2008). *Relative accuracy* refers to an individual's ability to predict correct and incorrect responses on an item level (Perfect & Schwartz, 2009). Some common measures of relative accuracy include the *phi* (ϕ) correlation and the Goodman-Kruskall gamma coefficient, *G*, both of which correlate confidence on item responses over trials to item accuracy (Flemming

& Lau, 2014). More recent, complex statistical instruments, such as *meta-d'*, attempt to control for the tendency for negative feedback, being informed that a high confidence guess was wrong, to elicit fewer high confidence guesses in successive items (Maniscalco & Lau, 2014).

Absolute accuracy describes the assessment of the calibration between an individual's overall self-assessed level of performance and their actual performance (Rivers et al., 2019). Absolute measures of calibration have been found to be more stable than relative measures (Mengelkamp & Bannert, 2010). Such metrics have been used to examine differences in metacognitive calibration between males and females (Gutierrez & Price, 2016), calibration differences between gifted and non-gifted students (Snyder et al., 2011), and the role of metacognitive judgments as moderators of learning in problem-solving tasks (Mihalca et al., 2017).

Concern regarding metacognitive confusion is not unique to the context of Google use. Students routinely demonstrate poor calibration between their perceived levels of knowledge or ability and their actual performance (Blake & Castel, 2015; Hartwig & Dunlosky, 2017; Saenz et al., 2017). Learners appear to regularly demonstrate overconfidence in their own judgments of learning after initial exposure to new material; only continued learning experiences and trials correct unperceived misunderstandings and incrementally correct their metacognitive calibration (Sanchez & Dunning, 2018). A 2017 study by Foster et al. found that even after over a dozen exams, college students were overconfident in their metacognitive calibration, even when aware of their past performance and prior calibration errors. Similarly, individuals who encounter material or items they find interesting actually experience greater levels of overconfidence; they subsequently spend less time studying these topics (Senko et al., 2022).

Paradoxically, Phakiti (2016) found that learners evince a tendency towards greater overconfidence on difficult items than easy ones. Such findings speak directly to learners' reliance on search engines, as the vast majority of internet searches are presumably brief in nature, and would thus fail to afford the iterative, incremental learning experiences necessary to overcome initial overconfidence. For instance, students demonstrating less accurate metacognitive calibration use advanced informational representation sub-processes, such as drawing or summarizing, less frequently than more accurately calibrated students (García et al., 2016).

The medium upon which Google is utilized appears to have an impact on metacognitive accuracy as well; learners appear to be significantly more overconfident in their comprehension of text read on a screen compared to learners who read the same text on paper (Ronconi et al., 2022). Similarly, the medium of web-connected devices appear to fail to overcome, and may facilitate, our propensity to parrot answers or explanations without adequately understanding them. Rahwan et al. (2014) found that learners interacting in a collaborative online learning environment were prone to unreflective copying bias, being the propensity to award popularly held answers with more legitimacy and subsequently share such answers without necessarily understanding them. Further, Hamilton and Yao (2018b) found that individuals who were granted access to the internet via a laptop perceived significantly greater internal knowledge than participants without such access, while individuals who accessed web searches via their personal cell phones perceived still greater inflated perceptions of internal knowledge.

Such findings comport to Ackerman and Goldsmith's (2011) conclusion that screen reading is associated with more erratic study times and worse metacognitive calibration than participants reading material on paper. In Ackerman and Goldsmith's study, participants short expository texts on one of two media, either screen or paper. Participants were then asked to predict their performance on a subsequent assessment of the texts. When participants were forced to expend identical time studying in both conditions, there was no significant difference in either prediction accuracy or performance; however, when participants were allowed to self-regulate their own study time, the screen-reading group evinced worse performance and worse calibration, attributable largely to less stable regulation of study time in the on-screen group. What is potentially insidious about the impact of screens as a medium of study is that children, like adults, appear to be unaware of the detrimental impact on comprehension of screen reading (Halamish & Elbaz, 2020). Conversely, Jeon and Gweon (2021) found that participants evinced similar reading comprehension across both screen and print reading media, but experienced shorter fixations, or pauses on particular words, and less reading fatigue with print. Moreover, screen reading has been shown to lead to more superficial information processing relative to other media (Delgado & Salmerón, 2021).

Regardless of the exact mechanisms at play in screen reading, the overconfidence elicited by web searches carries substantial risks to learning. Students who overestimate their cognitive performance spend less time studying and evince worse metacognitive control processes and executive functions than their relatively underconfident peers (Destan & Roebers, 2015), being more likely to underachieve (Dunlosky & Rawson, 2012). Perhaps unsurprisingly, students who utilize inaccurate prior knowledge evince greater metacognitive miscalibration (van Loon et al., 2013). In turn, Salovich and Rapp (2021) found that individuals who are generally poorly metacognitively calibrated are susceptible to inaccurate information. Zhao & Ye (2020) found that better calibrated learners not only evince higher achievement, but actually spend less time studying than more poorly calibrated peers. Individuals have been shown to subjectively experience inflated confidence relative to actual recall when they are asked to gauge their understanding while still in possession of study materials; the mere accessibility of an external information store inflates our self-assessment of internal knowledge, (Koriat & Bjork, 2005). Students who are accurately metacognitive calibrated or underconfident produced higher quality written responses in Wang and List's 2019 study on metacognitive calibration and written expression. Similarly, learners demonstrate higher levels of confidence with material, which is easily or more quickly retrieved, indicating that ease of retrieval is a dominant variable in judgments of learning (Kelley & Lindsay, 1993).

Potentially compounding the learning challenges associated with web searches is the way such searches influence future behavior (Firth et al., 2019; Marsh & Rajaram, 2019). Ferguson et al. (2015) found that participants with internet access were significantly less likely to volunteer answers than participants without the internet and were significantly faster to determine that they did not know an item. In this study, participants were assigned to one of two treatment conditions: internet access and no internet access. They were then administered an assessment of general knowledge. During this assessment, participants in the no internet condition could either type in an answer if they felt their internal knowledge warranted an attempt at the item, or they could type *NA* if they had no reasonable answer. Participants in the internet condition were asked to type in the answer if they knew it, or search for the answer on the internet if they did not. Answers and search behaviors were recorded. The results indicated that participants who were in the no internet condition answered significantly more questions from their own internal knowledge correctly than those in the internet condition and attempted significantly more questions. Conversely, participants in the internet condition appeared to be less willing to venture an answer from their own internal knowledge, and when they were, performed worse, indicating that the internet can undermine the metacognitive processes that help us determine what we do and do not know.

A plausible explanation for this phenomenon is found in a study by Risko et al. (2016), in which the researchers demonstrated that individuals who know they have access to externally stored answers evince significantly less persistence in completing items themselves, and further, were unaware of the influence answer availability had on their persistence time. The impact of diminished patience as a variable within web searches is a growing area of future research. In a relevant study, individuals who were resistant to effortful and time-consuming analytical thinking were more likely to rely on the internet via their smartphones, a phenomenon called cognitive miserliness (Barr et al., 2015). Barr's study further found that individuals who were more likely to engage in analytical thinking were less likely to utilize their smartphones as external memory sources. This may be one of the reasons the very presence of the internet in users' pockets seemed to reduce participants' willingness or ability to engage in effortful thinking (Ward et al., 2017). Similarly, Dunn et al.'s (2021) study on the influence of internet availability on metacognitive confidence demonstrated that when individuals searched the internet and found an answer that was actually wrong, the average estimate that their answer was correct was 75%.

The variable of *patience* also helps tie together the variables of epistemic curiosity and metacognitive bias. FitzGibbon et al. (2020) hypothesized that individuals experience greater motivational salience towards knowledge gap-closing information seeking if they perceive that information is immediately available as opposed to being available after future learning. Such a hypothesis highlights the dichotomy between interest-based curiosity, which is information seeking behavior elicited by one's expectation of pleasure wrought by learning, and deprivation-based curiosity, or information seeking behavior elicited by a knowledge gap yet to be filled (Litman & Spielberger, 2003). This dichotomy presents the pressing research question regarding whether or not more epistemically curious individuals would be more patient to fill a knowledge gap, indicating interest-type deprivation and, hypothetically, less prone to Google-induced metacognitive bias, or if deprivation-type curious individuals predominate and are more prone to such bias.

Conversely, participants in the no-internet condition in Dunn's experiment experienced relative underconfidence. Underconfidence need not be viewed as intrinsically negative; it is potentially demonstrative of higher curiosity and productive struggle (Giebl, et al., 2021). For instance, Dunn found that first requiring students attempt new learning without the aid of the internet, *before* letting them use online search functions, led to a significant increase in future recall, relative to participants who immediately engaged in internet-aided learning. Such findings not only support instructional practices which slow down a learner's thinking and elicit productive struggle, but further provide a framework through which Google may be used in educational settings in less deleterious applications. Furthermore, it provides support for Ausubel's (1968) contention that advanced organizers and pre-assessments allow for more meaningful learning. Pieschl's (2019) finding that problem-solving is particularly hampered by internet searches is subsequently well-aligned to the constructivist framework. Accordingly, Nestojko et al. (2013) concluded that transactive memory partners, while useful, are not feasible substitutions for internally stored knowledge, since such knowledge is fundamental for learning processes.

There appears to be reason for optimism, however. Salovich and Rapp's 2021 study found that metacognitive accuracy can improve through the implementation of reflective tasks during activities. Van Laer and Elen (2019) documented that learners who are cued to metacognitively calibrate within lessons demonstrate better overall calibration and learning outcomes than learners who do not. Both rubrics and idea-level unit standards have been shown to improve calibration accuracy (Hawthorne et al., 2017; Nederhand et al., 2018). It appears that student calibration accuracy can improve with explicit training in self-evaluation and metacognitive monitoring (Osterhage et al., 2019; Roberts et al., 2012).

Cognitive Offloading

Due to the finite nature of humans' memory capacity, we routinely opt to store to-be-remembered information in an external source for later retrieval; perhaps the simplest example of this ubiquitous human behavior is note-taking (Park et al., 2022). Such use of external sources as memory partners is termed *cognitive offloading* (Risko & Gilbert, 2016). Humans offload in order to lessen cognitive loads on their memories. One might, then, consider Google to be the ultimate external memory system; it is fast, ostensibly infinite, and thanks to the internet, always available. There are, however, significant risks associated with offloading, even with less powerful external memory stores. The act of offloading frequently appears in tandem with individuals intentionally forgetting, opting not to encode information, as a strategy to offload more information to external stores (Eskritt & Ma, 2014). We spare our working memories the work of encoding items into long-term memory, freeing cognitive resources to store materials externally. This process gains more importance when seen in the context of Knowlton and Castel's (2022) framework of value-directed remembering, which posits that successful use of targeted remembering requires accurate metacognition in order to selectively, and impromptu, attach greater value to, and thus the intention to later encode, targeted items.

Value-directed remembering is a metacognitive strategy in which individuals consciously or unconsciously parse encountered information by how valuable they deem that information, with high value information being recalled with fewer incidental details, suggesting that the act of assigning value to discrete bits of information is facilitated at least in part at the expense of *irrelevant* information (Hennessee et al., 2017). From the constructivist perspective, this raises a flurry of concerns. First, the ability to assign value to information necessarily requires prior knowledge to contextualize the newly encountered material (Nestojko et al., 2013; Subasi, 2019). Determining what is irrelevant and what is relevant is a metacognitive skill which itself requires knowledge and accurate metacognitive calibration (Medina et al., 2017). Similar to how a threshold of prior knowledge and metacognitive accuracy is a prerequisite for curiosity (Metcalfe et al., 2020), the accurate valuation of newly encountered material requires internally held knowledge and awareness of what one does or does not already know. Hamilton and Yao (2018a), in their study on cognitive offloading's effect on memory calibration, wrote:

> Our findings are consistent with the notion that individuals misattribute outcomes and characteristics of technology to the self while judging their own knowledge, which have potential consequences on strategic control of memory decisions, such as when to strategically encode information. For instance, a student who uses Google to study for an upcoming exam by "confirming" definitions he thinks he "mostly" understands may be surprised when he is not able to recall the information from memory during the exam. (p. 266)

A significant set of problems arise, then, when we over-rely on external stores. Kelly and Risko (2022), for instance, found that increased reliance on offloading can compromise internal memory and degrade free recall when the external store is no longer available. Free recall is both evidence of, and a pedagogical tool towards, deeper encoding of high value information (Cohen et al., 2017). It is possible that a significant contributor to the accuracy issues associated with cognitive offloading is the extent to which individuals perceive the cost of offloading. When subjects perceive increased cost of cognitive offloading, they reduce the behavior, leading to worse short-term performance but more accurate long-term memory (Grinschgl et al., 2021). A potential hypothesis, then, is that overreliance on external memory stores, such as Google, interrupt the process of value-directed remembering, by confounding the bidirectional influence of free recall from internal memory and deep-level encoding.

It does, in fact, appear that when individuals rely on external stores, the efficacy of value-directed remembering is significantly reduced; the mere knowledge that the information waits for later external retrieval damages the cognitive valuation of discrete bits of new information (Park et al., 2022). Similarly, the offloading of information onto external stores was found to significantly increase false recall; individuals who believe they will have access to external stores evince decreased true recall of presented words and increased false recall of unpresented words (Lu et al., 2020). Offloading memory not only risks false recall, but the creation of false memories, as well. Risko et al. found in their 2019 study that participants who were allowed to offload to-be-recalled words were not only unaware when their word lists were secretly changed, but that they also frequently encoded the false addition into their memories when given access again to their external store, creating a false memory of a note they did not actually take. Recent research indicates that an emphasis on the costs, instead of the benefits, associated with offloading leads to better offloading decisions (Fröscher et al., 2022). The iterative nature of effective free recall practices, the metacognitive awareness necessary for effective value-directed remembering, the deleterious impact of offloading on value-directed memory, and the inability of individuals to detect manipulation in external stores may thus make Google a dubious candidate as an external memory partner.

Google's Influence on Metacognition

Human beings' relationship with technology has always revolved around the concept of delegation, the outsourcing of human tasks to someone or something else (Slack et al., 2015). Technological resources like Google "are not mere tools that do our bidding, but mediators that perform tasks in ways that make presumptions about who we are and convey expectations on our behavior, attitudes, and values" (Slack et al., 2015, p. 146). Google, like most internet technologies, conveys our collective obsession with ease, efficiency, and convenience (Carr, 2010). It is difficult to find evidence that Google communicates human values related to more contemplative modes of analytical thinking, since such endeavors are rarely quick or easy. The impact of such digital technologies on our cognitive lives is subsequently deserving of a thorough examination.

A key mechanism in metacognition is the *feeling-of-knowing*, an individual's internal "evaluation of the extent of one's available knowledge" (Litman et al., 2005, p. 560). Litman et al. found that feeling-of-knowing intensity is negatively correlated with epistemic curiosity and subsequent exploratory behavior, indicating that when individuals believe they have successfully retrieved information, their feeling-of-knowing increases such that their curiosity is largely satiated; it may also indicate that the more intrinsically curious an individual is, the less they perceive themselves to know. This could be a function of metacognitive misattribution; when individuals gain access to information they perceive as being derived from experts, they subsequently struggle to discern between their own knowledge and the expert's knowledge (Sloman & Rabb, 2016). Google may thus present users with persistent challenges in discriminating between external and internal knowledge, causing users to confuse the abundance of the internet's information with their own memories, and dramatically inflating their cognitive self-esteem (Ward, 2013, 2021).

Adrian Ward's 2021 study, comprised of eight experiments, shed significant light on such epistemic confusion. Using the 24 item Cognitive Self-Esteem self-report scale, Ward sought to examine the relationship between individuals' self-evaluations of their cognitive ability and Google use. Participants were split between two treatment groups, one of which was provided access to Google during a general knowledge assessment, and one without. All participants then completed the Cognitive Self-Esteem survey, answering items designed to assess, among other concepts, individuals' self-perceived cognitive ability and memory compared to others. It is important to note that the scale utilized was designed to quantify an individual's evaluation of their own intrinsic ability, as well as their ability to utilize external information sources to correctly answer questions or successfully complete tasks. Differences in cognitive self-esteem related to internal knowledge between the Google group and non-Google group can be inferred to be the product of source misattribution, since such a result would only occur if participants believed they already held the knowledge internally. Ward found that participants utilizing Google routinely self-reported greater confidence in their own internal knowledge than the non-Google group.

Ward conducted a follow-up experiment to add an additional layer of analysis, having participants take a second general knowledge assessment, but without the benefit of Google. Participants were asked to predict their performance on the second assessment prior to its administration. While the participants who had Google access in the preliminary assessment expressed significantly more confidence in their performance in the second assessment, they did not actually perform better, demonstrating significantly worse metacognitive calibration than the non-Google group, appearing to take credit for the knowledge they found online. These, and subsequent experiments by Ward, suggest that Google use both exacerbates, and is exacerbated by, “knowledge ambiguity,” or a flawed accounting of one’s own internal knowledge (p. 5). The connection between the connection between the phenomenon of cognitive misattribution and the physical, neural architectures which precipitate it has only recently been explored.

Internet searches’ impact on memory may well have a neural basis. An fMRI study demonstrated that individuals who engaged in an internet search behavior subsequently had decreased connectivity between the temporal gyrus, middle frontal gyrus, and the postcentral gyrus: these regions are largely responsible for memory retrieval (Liu et al., 2018). In this study, the researchers conducted fMRI scans to establish baselines for brain activity, followed by a six-day training interval in which participants were directed to use web searches to find answers to presented questions. During the post-training phase, participants completed an assessment on the previously provided questions, this time without the aid of the internet. The researchers, however, also provided unrelated, novel questions at random intervals. Participants were then asked to self-report impulses to utilize the web. The fMRI scans were utilized to compare pre-training activity with post-training activity, as well as the correlation between reported web-search impulses and divergent brain activity. The researchers not only found significantly divergent patterns of brain activity between the pre-training and post-training scans, but also significantly positive correlations between reported impulses and brain responses in the frontal areas, indicating that the short-term internet use increases future motivation to use the internet.

Storm et al.’s 2016 study on the impact of internet use on future internet reliance comports to Liu et al.’s (2018) findings. In their study, a series of experiments were conducted to determine the nature of the relationships between prior internet access, proximity to internet devices, and future internet use, within the context of answering trivial or general knowledge questions. Participants were divided into three treatment conditions:

- control, in which no trivia questions were asked;
- memory, in which participants were only allowed to answer trivia questions from memory; and
- internet, in which participants were allowed to use the internet to find answers (2016).

In the first phase, participants in the memory and internet treatments were asked 16 trivia questions, with half being considered difficult and the other half easy. The control group was not asked any trivia questions.

In the second phase of the experiment, a second battery of questions was asked, this time to all participants, with all participants being granted the option of using Google per their individual preference. The results indicated that participants who used the internet in the initial set of trivia questions were significantly more likely to use the internet on the second set of questions than either the memory group or the control group. A follow-up experiment demonstrated that increasing the distance between the participants and the computer during the second set of trivia questions decreased the likelihood of participants in all groups opting to use the internet; however, participants in the internet condition for the first battery of questions still opted to use the internet significantly more frequently than the other two groups, indicating that the use of the internet as a source of information can increase reliance on the internet in the future, even when access to the internet is made increasingly inconvenient (Storm et al., 2016). There appears, then, that the internet may be a threat to reliance on our own internal knowledge.

Google, with the efficiency of its algorithms and the speed of modern internet, represents an expanded threat (Firth et al., 2019). Search fluency, the efficiency with which an individual retrieves relevant information from an external memory system, is correlated with metacognitive overconfidence Stone and Storm (2021) found that individuals regularly predicted that they would accurately recall quickly found information more often than more slowly found information, even when the information gleaned quickly was in actuality more difficult, thus evincing lower actual recall. In Stone and Storm's study, participants were presented with 22 trivia questions, which were answered via computer. Participants were to indicate if they were presented with an item they already knew the answer to. For unknown items, participants were allowed to use Google as they saw fit. The computer measured participants' search times. After answering the questions, participants provided a confidence rating, on a scale of 0 to 100, on the likelihood they would be able to recall the answer later, without the help of Google. After a distractor task, participants were then assessed on the trivia questions. While participants judged items which were less fluent, that is, they took longer to find online, to be less likely to be remembered, and items which were more fluent took less time to find, the inverse was actually true (Stone & Storm, 2021). Participants were significantly more likely to successfully recall items which were less fluent. Such findings indicate that search and retrieval fluency provide an inaccurate internal perception of memory. A similar phenomenon can be observed with processing fluency.

Processing fluency is the subjective ease of processing information. Flanagin and Lew (2022) found that faster processing fluency regularly elicits higher metacognitive valuations of performance. This subjectivity makes fluency an experience-based cue, as opposed to an information-based cue. As Flanagin and Lew aptly summarized:

> Indeed, experience-based cues such as fluency (…) have long been known to influence people's metacognitive assessments such as judgments of learning (.…) Whereas information-based judgments are founded in domain-specific beliefs held in long-term memory, experience-based judgments are derived from the experiences of information

> processing itself (.…) In this manner, experience-based judgments arise from a subjective feeling that is implicit, largely unconscious, and a by-product of ordinary learning processes (p. 3).

These findings gain heightened pedagogical relevance given Google's unrivaled speed, and the findings from Thompson et al. (2013) that *decreased* fluency results in more frequent corrections of incorrect, intuitive responses. Flanagin and Lew (2022) found that the fluency of information retrieval appears to fundamentally change users' epistemic beliefs in web-based environments. Interestingly, while the least competent were more likely to overestimate their ability in general, the availability of web-based information may have a more profound metacognitive impact on more competent individuals, leading to more inflated estimates of future performance. Foster and Dunlosky (2022) found that delayed judgments consistently lead to improved judgment accuracy, a finding which would seem to run afoul of the hyper-efficient nature of internet devices and Google searches. Similar concerns abound regarding Google's pedagogical potential.

The focus on hyper-personalization and hyper-efficiency means returned search results are tailored for the individual user's locality, interests, and point of view (Vaidhyanathan, 2012). Hearkening back to this study's theoretical focus of constructivism, it bears repeating that while knowledge is constructed internally (Derry, 1996), the extent to which that learning is significant and worthwhile is largely dependent upon how challenging the new material is. This is the state of disequilibrium Piaget (1960) referenced. Google's unparalleled ability to customize content may undermine that necessary disequilibrium. Vaihyanathan's (2012) perspective carries with it not only psychological and educational considerations, but civic ones as well. Google's prioritization of personally curated, customized search results may be partially responsible for creating a world in which *a priori* beliefs are only reinforced and go unchallenged, highlighting and hardening differences between groups, as we collectively begin to become more and more confident in what we already think we know. Regarding the dangers of such customization, Vaidhyanathan wrote:

> However, if search results are more customized, you are less likely to stumble on the unexpected, the unknown, the unfamiliar, and the uncomfortable. Your web search experience will reinforce whatever affiliations, interests, opinions, and biases you already possess. The way we use the Web already offers us ample powers of customization that threaten republican values, such as openness to differing points of view and processes of deliberation (…) Tailoring search results to reflect who we already are and what we already know fractures us into different discourse communities that know what we know for certain (it's all over the Web, after all), but know different things for certain about the same things. This trend toward customization will be great for shopping, but not so great for learning (pp. 183-184).

The algorithmic, ever-increasing efficiency of conducting a web search thus increasingly mimics the speed of internal recall. Subsequently, the use of internet searches has repeatedly been associated with inflated estimates of knowledge, relative to actual capacity (Pieschl, 2019; Stone & Storm, 2021; von Hoyer et al., 2022; Ward, 2021). Paradoxically, the very salience and accessibility of Google-derived information appears to make such information less retrievable from internal memory systems (Fisher, et al., 2021). It is likely, then, that Google searches leverage our brain's predisposition for equating speed of recall with depth of knowledge, since in traditional scenarios where internal knowledge is being assessed, speed of recall can indeed be associated with how well an individual has encoded the information (Reber & Schwarz, 1999). It may be of no surprise, then, that individuals who are forced to rely on internal knowledge instead of external knowledge appear to evince significantly greater metacognitive accuracy (Dunn et al., 2021).

Learners are confronted with an array of challenges in accurately evaluating their own understanding. For instance, the accuracy of their judgments of learning is easily impacted by irrelevant emotions induced in the learner (Baumeister et al., 2015). Ståhl (2019) provided evidence that an individual's certainty of newly acquired knowledge is positively correlated with internet reliance. Such internet reliance is arguably an inevitable byproduct of our propensity for *cognitive offloading*—the act of utilizing external resources to reduce cognitive demand (Risko & Gilbert, 2016). Students increasingly utilize Google for cognitive offloading as part of a transactive memory system, essentially selecting to reduce what they have to know internally, thereby shifting metacognitive considerations from what to remember to where to find it (2016). Sparrow et al. (2011) found that when individuals could recall information, they were less likely to remember where they found it, and vice-versa. Within the framework of constructivism, these tectonic shifts in the way we think about thinking represent deep-seated epistemological threats (Ståhl, 2019). If the constructivist framework is valid, and internal knowledge is crucial for new learning, offloading and its potential for creating cognitive confusion is worthy of further inquiry.

The literature presented in this review provides an overview of research findings regarding the interactions between curiosity, Google, and metacognitive bias, as framed by the constructivist contention that prior knowledge is essential to new learning and problem solving. This is a timely topic which will only grow more and more relevant as smartphone adoption and Google use continue to accelerate. The pedagogical ramifications for how internet use impacts metacognition and learning behaviors are immense and pressing. Storm et al. (2016) determined that participants who answered one set of trivia questions with the aid of the Internet were significantly more likely to answer a new, easier trivia questions with the help of the Internet than were participants instructed to answer the first set from their own memories. The fMRI studies further indicated that internet use quickly changes brain activity such that users become dependent on the internet for unlearned skills (Wang et al., 2017), and more importantly, that the internet information-acquisition process is prone to challenges in information recall (Dong & Potenza, 2015). There is evidence, then, that Google use begets more Google use, even when it is not needed. It can be argued, then, that what is at stake in the classroom is the intellectual and cognitive independence of students, both in terms of their ability to construct internal knowledge, and to accurately monitor their own learning.

Summary

Constructivism, which posits that knowledge is internally constructed by the learner via the processing of discrete, external information in the context of the learner's prior knowledge and experiences, has been the foundational epistemological theory of public education for half a century. This process is theorized to involve the anchoring of new cognitive material upon schemata, which are themselves comprised of the learner's prior internal knowledge. Because this process leans heavily on the learner maintaining a modicum of encoded cognitive material, the introduction of cognitive offloading to the limitless and efficient external memory partner that is the internet represents a fundamental challenge to learning. Of equal concern is the extent to which the use of Google, due to the hyper-personalized nature of Google searches, the speed of the search, or the pedagogical practices which use Google, fail to elicit the productive struggle or desirable difficulty necessary for true learning. In this way, the fluency of retrieval from Google, however convenient, may very well represent a serious barrier to knowledge acquisition.

Similarly, these new informational technologies present myriad opportunities for epistemic confusion, wherein learners may confuse what they merely read online for their own knowledge, or more fundamentally question the need for internally knowing things at all. The literature previously reviewed paints a picture in which metacognitive accuracy appears to be foundational to learning, and supports the framework put forth by Risko (2019) that the intersection of technology and cognition must not be viewed as a kind of blank slate of research but should instead be contextualized by what we already know about human cognitive systems.

The compromising of epistemic curiosity, which is the desire for knowledge which serves to motivate new learning. thus becomes a ubiquitous obstacle. Because Google's information store is virtually infinite, and because of the ever-increasing efficiency of related searches, learners' epistemic curiosity may be perpetually at risk of being satiated even in the presence of substandard internal mastery of new material, since internet recall can now so closely approximate internal recall. Because the human brain intuitively places high premiums on efficiency and fluency, equating both with knowledge, information stored online and accessed at a student's leisure is often confused by the student as their own knowledge. This leads to substantial metacognitive biases, wherein learners drastically overestimate their own mastery of material encountered online, and their predicted future recall of such material is grossly inflated relative to actual recall.

There exists, then, a need to better understand both the interactions and strength of such interactions between these variables. If Google searches are responsible for a decrease in epistemic curiosity but an increase in epistemic confusion, including metacognitive bias, such findings would potentially cast doubt on the notion of curiosity as an internal, stable construct, and have a direct impact on both policy decisions in public education and on directions for future research. Conversely, if epistemic curiosity can be found to moderate the metacognitive impacts of internet searches, epistemic curiosity would signal the need to research pedagogical practices which accommodate the varying needs related to the different levels of epistemic curiosity represented in student populations, particularly regarding how internet searches are employed in instructional settings. If it is determined that intrinsic epistemic curiosity moderates the impact of Google-related metacognitive bias, it could provide a new avenue of differentiated instruction, especially regarding use of internet applications. Such findings would also underline the need for the explicit metacognitive instructional practices utilized to increase metacognitive accuracy in numerous studies (Hawthorne et al., 2017; Nederhand et al., 2018; Roberts et al., 2012; Salovich & Rapp, 2021; van Laer & Elen, 2019).

CHAPTER THREE: METHODS

Overview

The purpose of this quantitative experimental posttest-only control-group study is to determine if there is a difference in levels of metacognitive bias between high school students who are granted access to Google on a practice assessment and those who are not, after controlling for epistemic curiosity. This chapter introduces the design of the study, including definitions of variables, the research question, and the null hypothesis. Chapter three will establish the rationale for this study's methodology and design, before providing a comprehensive explanation of the study participants, setting, and instrumentation. Finally, this chapter will provide a detailed account of procedures utilized for the statistical analysis of the data.

Design

This research study used a true experimental, posttest-only control-group design, since its samples were derived via random sampling, with participants randomly assigned to either a comparison group, wherein participants did not receive the experimental treatment, or an experimental group, wherein participants did receive the experimental treatment (Gall et al., 2007). Because a defining characteristic of a true experimental design is the random assignment of participants to treatment groups, participants in this study were randomly assigned to either the experimental group or the control group. Experimental designs are utilized when the researcher seeks to establish a cause-and-effect relationship of the treatment on the dependent variable (Gall et al. 2007), in this case, metacognitive bias. Such a design is particularly fitting to this study, which was designed to examine the potential impact of Google use on metacognitive bias, examining the difference between an individual's subjective perception of their performance and their actual performance (Dunlosky & Bjork, 2013; Fleming & Lau, 2014). This study further seeks to statistically control for the effect of individual differences in epistemic curiosity, defined as the "desire for knowledge that motivates individuals to learn new ideas, eliminate information-gaps, and solve intellectual problems" (Litman, 2012, p. 1).

Similar experimental designs have been used frequently in studies exploring the interaction between internet use and cognition, utilizing differing internet treatments within study intervals, pre-tests, and practice assignments, with both simple recall questions and open-ended items utilized (Dunn et al., 2021; Fisher et al., 2015; Ward, 2021). This study utilizes global prospective predictions, since such judgments can be thought of as "a type of self-efficacy judgment," and therefore better aligned to a study examining overconfidence (Dunlosky & Bjork, 2013, p. 433). Measures of absolute accuracy also typically demonstrate better reliability than relative measures (Maki et al., 2005).

Prior research has indicated that metacognitive bias on one task is significantly correlated with metacognitive bias on subsequent tasks, even across different cognitive domains (Mazancieux, et al., 2018). Thus, while the current study utilized an assessment focusing on discrete facts, or "expressive knowledge" (Jain, 2002, p. 179), it is intended to function as an introductory examination of Google's relationship with metacognitive bias and epistemic curiosity's impact as a covariate across cognitive domains and knowledge types. Further research will nonetheless be needed to adequately address specific differences in Google-related bias within each domain.

Within the current study, the independent variable was Google access, where half of the participants were allowed to use Google to *confirm their answers* during a 10-item practice activity, while the other participants were not. The dependent variable was metacognitive bias, the signed difference between predicted or judged performance and actual performance (Dunn et al., 2021; Rivers et al., 2019). The covariate was epistemic curiosity, as measured by Litman and Spielberger's (2003) Epistemic Curiosity Scale, with individual Likert responses summated into a single overall curiosity score.

Research Question

RQ: Is there a difference in metacognitive bias scores among high school students who are allowed to utilize Google on a practice activity prior to a general knowledge assessment and those who are not, when controlling for epistemic curiosity?

Hypothesis

H_0: There is no difference in metacognitive bias scores among high school students who are allowed to use Google on a practice activity prior to a general knowledge assessment and those who are not, when controlling for epistemic curiosity.

Participants and Setting

This section will provide a description of the population from which the sample was created, the sample size, and what sampling technique was used. In addition, this section provides a description of the participants who comprise the sample, as well as the setting from which the sample was derived.

Population

The population utilized in this study was comprised of two high schools in South Carolina. Their common features, which allow them to be treated as a single population, are that they are comprised of rising 10th through rising 12th grade high school students in a public high school setting. The aggregate demographic breakdown of the combined population was 11.6% African American, 74.6% White, 7.2% Hispanic, 2.9% Asian, and 2.9% multiracial or other. The combined population was 52% male and 48% female. The average age for the combined population was 16 years old. The mean poverty index was 36.2.

High School A, a rural school in the upstate of South Carolina, had an enrollment of 1,202 students. Within this school population, 54% were male and 46% were female. Seven percent were African American, 81% were White, 7% were Hispanic, 1% were Asian, and 4% were multiracial or other. The average age at High School A was 16 years old. High School A maintains a 1:1 Chromebook initiative and relied heavily upon learning management systems for its instructional program. High School A had a poverty index of 34.7.

High School B is a suburban school in the upstate of South Carolina, with an enrollment of 999 students. Within this population, 51% were male and 49% were female. Ten percent were African American, 73% were White, 10% were Hispanic, 3%, were Asian, and 4% were multiracial. The average age at High School B was 16 years old. High School B was in the same district as High School A, and thus maintained a similar 1:1 Chromebook initiative and attendant digital instructional platforms. The poverty index at High School B was 37.7.

Participants

In this study, the number of participants sampled was 140, exceeding the minimum of 130 calculated by G*Power (Faul et al., 2007) when assuming a medium effect size, alpha set at .05, and power of .80. See Appendix C for the G*Power calculation. This sample size also exceeds the minimum algorithmically derived sample size recommendations established in at least two prior studies (Borm et al., 2007; Shieh, 2019).

Participants were randomly sampled, via random number generator, from a population comprised of the student body of two public high schools, both in the state of South Carolina. All eligible enrolled students were assigned a numerical combination and maintained equal chances of being selected. Selected students received letters of invitation to participate and a phone call from the researcher. The acceptance rate was 98%. Random drawings continued until the minimum *n* for each group was met.

At High School A, the sample of 70 participants was divided evenly among the control and experimental groups via random assignment. The experimental Google access group had a demographic breakdown of 5% African American, 83%, White, 6% Hispanic, 1% Asian, and 4% multiracial or other, with a mean age of 16. The control group had demographic breakdown of 7% African American, 79%, White, 6% Hispanic, 1% Asian, and 4% multiracial or other, with a mean age of 16. At High School B, the sample was identically divided among the control and experimental groups, again via random assignment. The experimental Google access group had a demographic breakdown of 15% African American, 68%, White, 9% Hispanic, 4% Asian, and 2% multiracial or other, with a mean age of 16. The control group had demographic breakdown of 13% African American, 73%, White, 9% Hispanic, 4% Asian, and 2% multiracial or other, with a mean age of 16.

Setting

All instruments were computer-administered via Qualtrics within a classroom on the home campus of the participants. Each campus site was comprised of 70 students randomly selected via random number generator, then randomly assigned to either the control group or the experimental group. On both campuses, each of the two testing sites, which were classrooms on their home campus, contained 35 participants. Both groups took their assessments on the same day and at the same time. In both groups, participants were assigned a ticket with a number which corresponded to a specific computer/testing station and directed upon entrance to sit at the appropriate location. Groups were homogenous and independent; the 35 participants in the experimental group all tested within the same room, while the 35 participants in the control group tested in a different room. In both treatment groups, both participant groups took identical practice assessments. Participants in the control group took the practice activity without the aid of Google. Participants in the experimental group were read an altered script instructing them to use Google to confirm their answers on the practice activity.

Instrumentation

All instruments in this study have been validated and utilized in multiple studies. The researcher received written permission to use the instruments utilized in this study. Litman and Spielberger's (2003) Epistemic Curiosity Scale was used to quantify participants' curiosity, which serves as the covariate. Items from Tauber et. al.'s (2013) re-normed list of Nelson and Narens' (1980) general knowledge norms were used in both the practice activity and assessment. To quantify metacognitive bias, which serves as the dependent variable, the signed difference score was calculated by subtracting the actual performance from the predicted performance (Dunlosky & Metcalfe, 2009).

Litman's Epistemic Curiosity Scale

Litman and Spielberger's Epistemic Curiosity Scale (2003) was developed in order to "determine whether epistemic curiosity could be identified as a meaningful personality construct," and to "assess individual differences in epistemic curiosity" (p. 77). The creator of the scale has only reported the need for a separate scale for young children, ages 3-8, due to their known differences in behavioral expressions of curiosity (Piotrowski et al., 2014). All studies cited in this chapter validating or utilizing the epistemic curiosity scale enlist participants who fall within the upper age range of the high school demographic, being 18 years of age.

The scale was created by administering four psychometric tests measuring personality traits related to curiosity, such as openness to new experiences and tendencies towards exploratory behavior. The four assessments utilized were Collins' Perceptual Curiosity Questionnaire (1996), Spielberger et al.'s State-Trait Personality Inventory (1979), selected subscales of Pearson's Novelty Experiencing Scale (1970), and selected subscales of Zuckerman's (1979) Sensation Seeking Scale. After administering the battery of assessments to 739 university students, Litman and Spielberger conducted exploratory factor analyses, separately for men and women, to pare the aggregate list of 56 items first to 28, by selecting the items with the most dominant loadings on epistemic curiosity, and then to the final item total of 10, by selecting the 5 items with dominant loadings on the diversive and specific subtypes, respectively. The combined epistemic curiosity scale demonstrated Cronbach's alpha of .81 and .85 for men and women, respectively, indicating good internal consistency. The diversive subscale demonstrated a Cronbach's alpha of .80 and .81 for men and women, respectively, while the specific subscale demonstrated a Cronbach's alpha of .71 or greater for both sexes.

Litman's Epistemic Curiosity Scale has subsequently been used in multiple studies, incorporating a diverse body of participants, from Doctor of Pharmacy candidates to school counselors, to high school students (Baker et al., 2020; Malcom et al., 2020, Tang & Salmelo-Aro, 2021). This study utilized the overall epistemic curiosity score. Consistency has been demonstrated in both American populations (Litman & Spielberger, 2003), as well as in a German population, with an alpha of .84 for the overall epistemic curiosity scale (Litman & Mussel, 2013).

The instrument employs a Likert design, in which respondents read a statement and subsequently indicate how they generally feel on a scale of 1 through 4, with 1 indicating *almost never*, 2 indicating *sometimes*, 3 indicating *often*, and 4 indicating *almost always*. An example of one such item is *When I see a complicated piece of machinery, I ask someone how it works*. Overall responses and subscale responses can be summated such that the higher the sum, the greater the level of epistemic curiosity or subtype is indicated, where scores closer to 40 evince greater epistemic curiosity, and aggregate scores closer to 0 indicate less epistemic curiosity. The procedure for its administration is included in the proctor script, Appendix D. The completion of the 10-item scale should take no more than 10 minutes. The author of the instrument granted blanket permission for use of his psychometric instruments for educational and research purposes (http://drjlitman.net/).

Nelson and Narens' General Knowledge Norms

The 300-item general knowledge question bank developed by Nelson and Narens (1980) was designed to provide a large set of general information question items which could be used in memory and metacognition research, and which would be supplemented by normative data on the probability of correct recall on individual items, allowing for researchers to select items of specific difficulties for individual studies. Observed fluctuations in popular knowledge across generational cohorts created the need for re-norming. When the instrument was re-normed via re-administration to over 600 students, items with incorrect answers were updated and corrected, as were norms for probabilities of correct recall (Tauber et al., 2013).

For the development of the scale, items were derived from a wide array of sources, such as fact books, trivia books, atlases, and colleagues. The questions were administered to 270 students on two different campuses. Participants answered the 300 questions, and then reported on their feeling-of-knowing for items they had answered incorrectly. The feeling-of-knowing scale ranged from 1 to 9. Overall accuracy was scored as a percentage in decimal form. Data for each test item included probability of correct recall, probability of recall disaggregated by sex, probability of recall disaggregated by campus location, median latency (amount of search time) for correct answers, median latency for incorrect answers, and the median feeling-of-knowing for incorrect answers. Latency was reported by median response times in seconds, while feeling-of-knowing was reported as the median response on the Likert-like FOK scale.

Data analysis on the two campus subgroups demonstrated very strong correlations in relative difficulty across location, where $r = .976$, $p < .001$. When analyzing for consistency between men and women, the researchers found a correlation between probability of correct recall between men and women of .933. An independent samples *t* test indicated 142 items evinced significant generational differences in recall between the 1980 and 2012 administrations. Of these 139, significantly lower probability of correct recall was demonstrated. This was attributed to dated content within items. Nonetheless, the Spearman correlation, with a set *p*-value of .001, was .83, indicating good generational stability. Spearman correlations of item rank orders between the two locations demonstrated consistency across locations, with a correlation of .94, $p < .001$.

Nelson and Narens' original norms are among the most widely utilized psychometric instruments in the field of psychology, utilized dozens of times to explore, among many topics, confidence ratings and judgments of learning, the role of prior knowledge, and the impact of aging on metacognitive processes (Marsh et al., 2003; Metcalfe & Finn, 2012; Winne & Muis, 2011). Tauber's re-normed iteration of Nelson and Narens' general knowledge items have been recently used for similar purposes (Sitzman et al., 2014; Sitzman et al., 2020).

For the purposes of the current study, items with a variety of difficulties were selected only from the 157 items which did not demonstrate significant generational differences in performance. Ten items were pulled for the practice assessment. Twenty such were pulled from the 300 item bank of general knowledge norms for the final assessment. The same items were utilized for both the practice and final assessment for both treatment groups.

Metacognitive Bias

The dependent variable of metacognitive bias has been quantified here by subtracting actual performance from the predicted performance, as outlined by Dunlosky and Bjork (2013), Dunlosky and Metcalfe (2009), and Perfect and Schwartz (2009), and utilized by Dunn et al. (2021), Fisher et al. (2021), Fisher and Oppenheimer (2021), Saenz et al. (2017), and Tirso and Geraci (2020). The larger the difference between the two values, the greater the metacognitive bias. Positive values indicate metacognitive bias manifesting as overconfidence, while negative values indicate underconfidence. Because both the predicted and actual scores are percentages, signed difference scores may range from -100, wherein a participant predicted a score of zero, but received a 100, and +100, wherein a participant predicted a 100 but received a score of zero.

Procedures

After discussing the purpose and goals of the study with the two districts and campus principals, the researcher submitted the proposal for approval to both the districts and Liberty University, which were approved. The IRB application (Appendix G) received approval from Liberty University (Appendix H), after which the researcher collaborated with campus administration for the sampling process. All students on both campuses were randomly assigned a numerical combination. A random number generator was used for selection. Numbers were drawn until the minimum sample size was met. Parents of selected participants were notified via email provided by campus information services, as well as mailed letters (Appendix F). In accordance with IRB policy, consent from parents of participants who were 15-17 years old in less intrusive studies may be gained through opt-out forms. Forms (Appendix E) were mailed and emailed to parents and students. Participants also provided assent on the first form of the Qualtrics survey on the day of the assessment.

The study utilized identical designs on both campuses. One hundred thirty-seven participants were randomly assigned to one of two groups via a random number generator. Participants were assessed in a classroom on their home campus. Students were provided instructions on their computer screen, as well as orally. The researcher and a recruited administrator at the campus site followed the identical instruction scripts (Appendix D) and procedures. Participants first completed the epistemic curiosity scale. While this was untimed, all participants completed the 10-item task within 12 minutes. Participants were not allowed to move on to the next stage of the assessment until prompted, to ensure that all participants progressed through the study in the same general timeframe. This was done to mitigate the risk of students perceiving that they were *behind* and needed to rush. Items were selected from Nelson and Narens (1980) general knowledge norms, with a mean correct response rate from Tauber et al.'s 2013 re-norming of .501 and a standard deviation of 12.11. Participants answered items by typing their answer into the response field. Incorrect spelling did not disqualify answers from being marked correct if the content of the answer was otherwise correct.

The control group completed all 10 items without intervention. In the experimental group, the proctor indicated that, per the script provided in Appendix D, participants could use Google to *confirm* their answers. After completion, participants were provided a brief break, while internet histories and caches were cleared, and the final general knowledge assessment was loaded. Participants in both groups were instructed per the proctor script to complete the general knowledge assessment without the aid of Google or any internet tool. All participants completed the final assessment within 37 minutes. After all participants completed the test, they were provided their scores, thanked for their participation, and dismissed.

All data and materials were stripped of personal identifying information, in accordance with IRB guidelines. Assessments in Qualtrics, as well as aggregated data on the researcher's computer, were password protected. All computers utilized for the study had their browser histories and caches cleared. The researcher proceeded to analyze the data with appropriate statistical tests. The scrubbed data will be secured and maintained for three years, after which all files will be permanently deleted.

Data Analysis

A one-way ANCOVA was used to analyze the data. ANCOVA was selected in order to determine if any significant differences in metacognitive bias between the Google and non-Google groups survive after controlling for different levels of participant epistemic curiosity. The independent variable of Google access is categorical, while the dependent variable of metacognitive bias is continuous numeric data. The covariate, the summated epistemic curiosity score, is similarly comprised of continuous numeric data. The two treatment groups at each campus are entirely independent, with participants being randomly assigned to only one of the two groups. Because curiosity, like most psychological constructs, presumably exists on a continuum, the use of ANCOVA to analyze curiosity's potential impact of metacognitive bias appears to be the most appropriate tool for data analysis.

Before performing the ANCOVA, the researcher performed preliminary data screening and assumption testing. Box plots were analyzed to check for outliers. The researcher screened data to ensure each participant had data for each of the variables. Variable types and levels were checked, with the dependent variable at the interval or ratio level and observations in the independent variable confirmed as independent. To examine normality, a series of histograms were created for the covariate, epistemic curiosity, and the dependent variable, metacognitive bias, and Shapiro-Wilks was used to verify. To check for bivariate normal distribution, a scatter plot between the pre-test variable and post-test variable for each group were analyzed for the classic *cigar shape*. In order to satisfy the assumption of homogeneity of slopes and check against treatment-by-covariate interaction, the researcher checked for interactions by conducting a preliminary ANCOVA using the SPSS GLM procedure with a custom model, including the covariate-independent variable interaction term, as recommended by Warner (2021), and also performed a one-way ANOVA to determine if there was a significant interaction between curiosity and Google access. To test for equal variances in each group of the independent variable, Levene's Test of Equal Variance was utilized.

To answer the RQ, a one-way ANCOVA was used to determine if there was a significant difference in metacognitive bias scores between treatment groups after controlling for epistemic curiosity scores. Descriptive statistics were reported, including the mean and standard deviation for each group. An alpha level of $\alpha < .05$ was set for each hypothesis, with eta squared reported for effect size. After assumption testing, the results of the ANCOVA analyses were analyzed and reported, including the number, number per cell, degrees of freedom (within and between), *F* values, and significance level.

CHAPTER FOUR: FINDINGS

Overview

Chapter four will begin with an analysis of the descriptive statistics rendered from the data collected. This will be followed by a description of the data screening procedures for the analysis of covariance. The rest of the chapter will present and interpret the results of the null hypothesis, which will focus on the ANCOVA results for the Google and Non-Google groups of the experiment.

Research Question

RQ: Is there a difference in metacognitive bias scores among high school students who are allowed to utilize Google on a practice activity prior to a general knowledge assessment and those who are not, when controlling for epistemic curiosity?

Null Hypothesis

H_0: There is no significant difference in metacognitive bias between high school students who are allowed to utilize Google on a practice activity prior to a general knowledge assessment and those who are not, after controlling for epistemic curiosity.

Descriptive Statistics

Descriptive statistics were obtained on the covariate (epistemic curiosity), dependent variable (metacognitive bias), and the adjusted dependent variable (adjusted means for metacognitive bias) for each group (See Tables 1, 2, and 3). Out of 140 students selected to participate, 2 opted out, and 1 participant entered blank answers on all questions, disqualifying his results. Subsequently, the total *N* for this study was 137. Tables 4 and 5 provide frequencies for the race and sex of participants.

Table 1

Descriptive Statistics: Covariate: epistemic curiosity

Group	*n*	*M*	*SD*
0 – No Google	68	24.10	4.83
1 – Google	69	24.30	4.91

Table 2

Descriptive Statistics

Dependent Variable: metacognitive bias

Group	*n*	*M*	*SD*
0 – No Google	68	24.65	16.51
1 – Google	69	29.61	13.74

Table 3

Descriptive Statistics

Dependent Variable (Adjusted Means): metacognitive bias

Group	*n*	*M*	*SE*
0 – No Google	68	24.39	1.06
1 – Google	69	29.86	1.05

The control group, which was not granted Google access on the practice activity, evinced a mean metacognitive bias score of 24.65 (*SD*=16.51), indicating that on average participants in the control group predicted they would perform almost 25 points better on the general knowledge assessment than they actually did. The experimental group, which was granted access to Google during the practice activity, evinced a mean bias score of 29.61 (*SD*=13.74). The mean curiosity score for the control group was 24.10 (*SD*=4.83), while for the experimental group the mean was 24.30 (*SD*=4.91). The overall mean bias score was 27.15 (*SD*=15.33), while the overall mean curiosity score was 24.20 (*SD*=4.85). The adjusted means for metacognitive bias were 24.39 (*SE*=1.06) for the control group, and 29.86 (SE=1.05) for the experimental group.

Table 4

Sex of Participants

	Frequency (*N*=137)	%
F	68	49.3%
M	69	50.0%

Table 5

Race of Participants

	Frequency (*N*=137)	%
Asian	4	2.9%
Black	16	11.6%
Hispanic	10	7.2%
Other	4	2.9%
White	103	74.6%

Results

The researcher selected ANCOVA for the statistical analysis in order to determine if any differences in mean metacognitive bias scores between the Google access groups survived controlling for epistemic curiosity. The null hypothesis was that there would be no significant difference in mean metacognitive bias between the Google and Non-Google groups after controlling for epistemic curiosity. Data screening and assumptions testing were first conducted to verify the appropriateness of ANCOVA.

Data screening was first conducted on each group's covariate and dependent variable. The researcher sorted the data on each variable and scanned for inconsistencies. No data errors or inconsistencies were identified. Box plots were used to detect extreme outliers in the dependent variable and covariate across both levels of the independent variable (See Figures 1 and 2). The quartiles for both appeared reasonably spaced, and no extreme outliers were identified. The researcher subsequently screened the data to ensure that the dependent variable and covariate were measured at the continuous level, with independent observations and no redundant membership in either treatment group.

Figure 1

Curiosity Score Box Plots by Google Access.

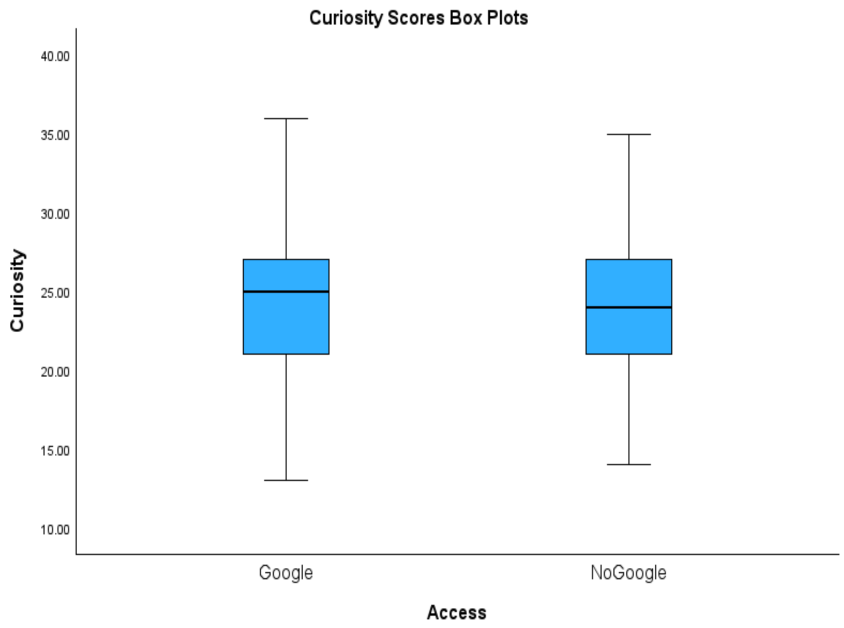
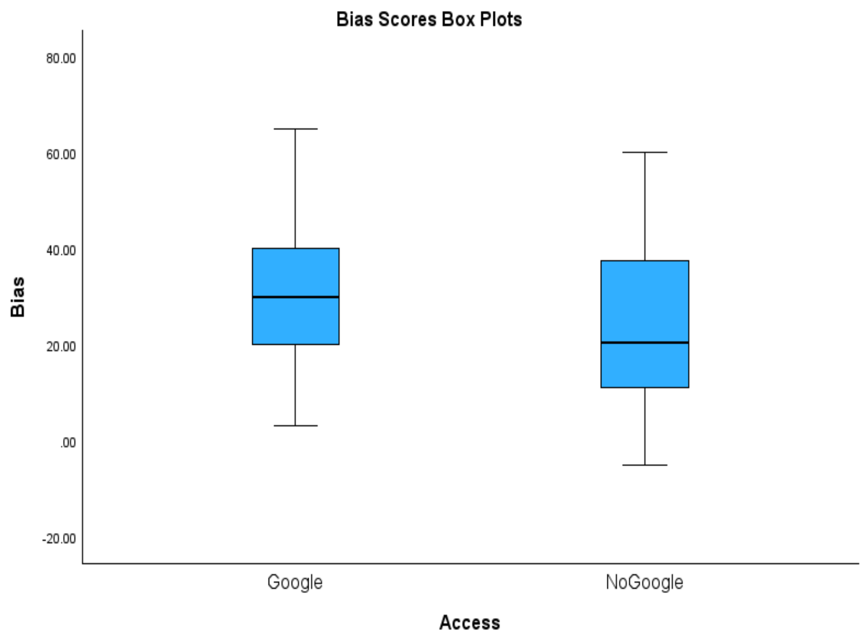


Figure 2

Metacognitive Bias Score Box Plots by Google Access.



Assumptions

An Analysis of Covariance (ANCOVA) was used to test the null hypothesis. The ANCOVA required that the assumptions of normality, assumption of linearity and bivariate normal distribution, assumptions of homogeneity of slopes, and the homogeneity of variance, are met (Warner, 2013).

In order to verify the satisfaction of the assumption of normality, the researcher created histograms for the covariate, epistemic curiosity, and the dependent variable, metacognitive bias (see Figures 3, 4, 5, and 6). The histograms evince relatively normal distributions, both overall and across treatment groups.

Figure 3

Histogram of Epistemic Curiosity Scores for all Participants.

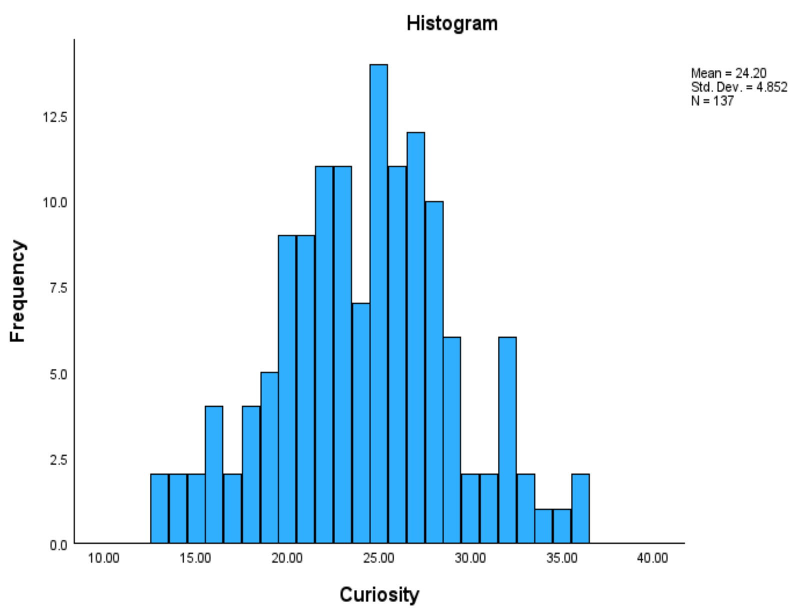


Figure 4

Histogram of Metacognitive Bias Scores for all Participants.

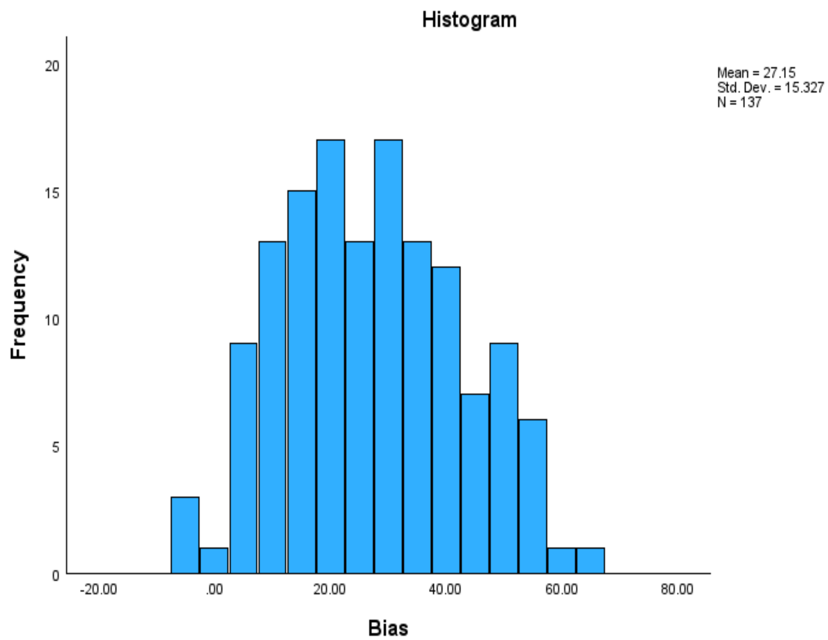


Figure 5

Histogram of Epistemic Curiosity Scores Across Treatment Groups.

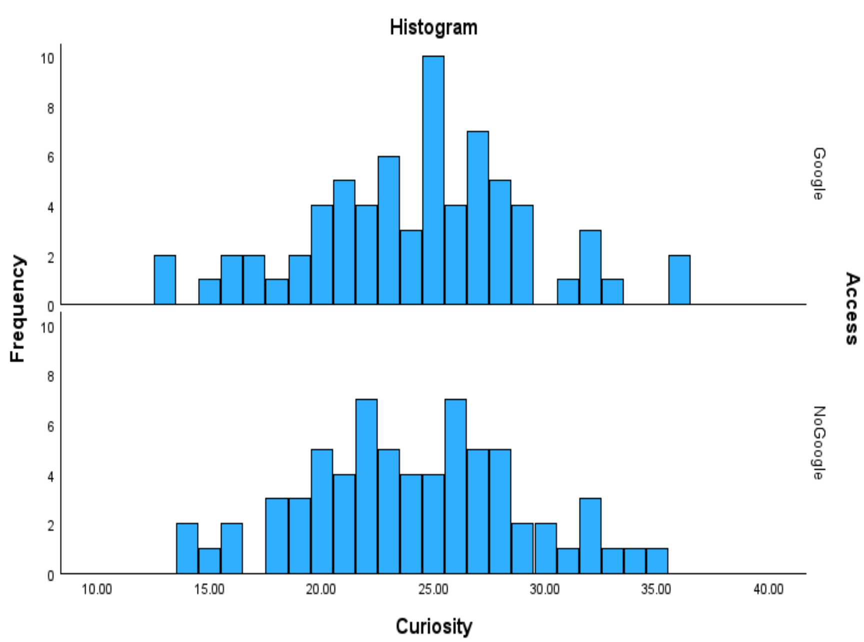
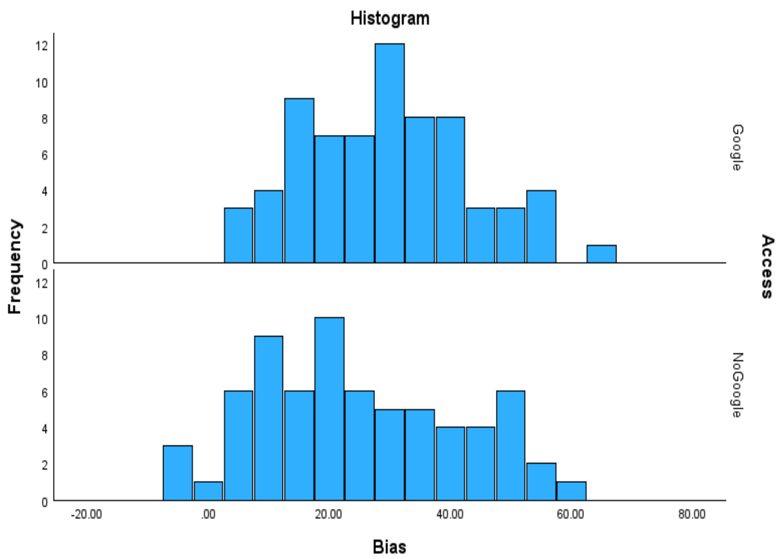


Figure 6

Histogram of Metacognitive Bias Across Treatment Groups.



The researcher also conducted Shapiro-Wilk tests for both the covariate and dependent variables (see Table 6). None of the tests indicated significance at the .05 level, further indicating that the assumption of normality is tenable.

Table 6

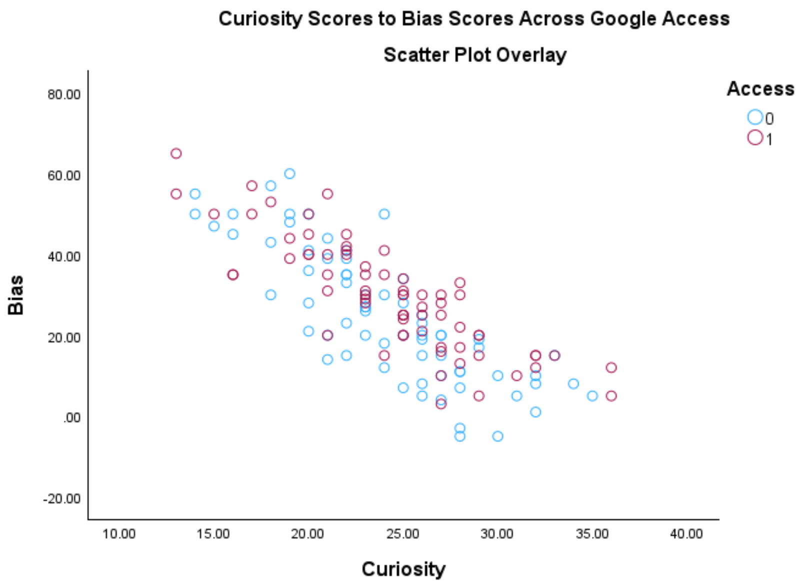
Tests of Normality

		Shapiro-Wilk		
	Groups	Statistic	*df*	Sig.
Curiosity	0 – No Google	.998	68	.766
	1 – Google	.985	69	.575
Bias	0 – No Google	.967	68	.068
	1 – Google	.984	69	.533

The assumption of linearity and bivariate normal distribution were tested using a scatter plot for each access group. Linearity was met and bivariate normal distributions were tenable, as the shapes of the distributions were not extreme, presenting instead with the classic *cigar shape*"(See Figure 7).

Figure 7

Covariate to Dependent Variable Scatter Plot by Treatment



To check for homogeneity of regression slopes, the researcher then conducted a preliminary ANCOVA using the SPSS GLM procedure with a custom model, including the covariate-independent variable interaction term, as recommended by Warner (2021). No interaction was found where $p = .171$. Additionally, the researcher then utilized a one-way ANOVA to verify that the assumption of homogeneity of slopes was not violated. The interaction ($p = .809$) was not significant. The assumption of homogeneity of slope was met. Finally, the researcher utilized Levene's Test of Equal Variance to satisfy the assumption of equal variance in each group of the independent variable. The result was not significant at the .05 level ($p = .063$), demonstrating that the assumption was met. As the data did not violate any of the assumptions set out by Warner, the researcher determined that ANCOVA could be used to address the research question of the study.

An ANCOVA was used to test the null hypothesis regarding mean differences in metacognitive bias between the non-Google group (M_{adj} = 24.39, *SE*. = 1.06) and the Google group (M_{adj} = 29.86, *SE*. = 1.05), when controlling for the covariate of epistemic curiosity. The null hypothesis was rejected at a 95% confidence level where $F(1,134) = 13.39$, $p<.001$, with a η_p^2 of .09. The partial eta squared of .09 indicates a medium to large effect size of Google access on metacognitive bias, after controlling for epistemic curiosity. Differences in adjusted means and the significance of those differences are reported in Table 7. ANCOVA results of between-subjects effects are reported in Table 8.

Table 7

Multiple Comparisons of Groups

Pairwise Comparisons

Dependent Variable: metacognitive bias

					95% Confidence Interval for Difference	
(I) group	(J) group	Mean Difference (I-J)	*SE*	Sig.[b]	Lower Bound	Upper Bound
0	1	-5.475*	1.496	.001	-8.435	-2.516
1	0	5.475*	1.496	.001	2.516	8.435

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Table 8

Tests of Between-Subjects Effects

Dependent Variable: metacognitive bias

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	21677.54	2	10838.77	141.43	<.001	.68
Intercept	41505.91	1	41505.91	541.58	<.001	.80
Access	1026.34	1	1026.34	13.39	<.001	.09
Error	10269.54	134	76.638			

The results of the ANCOVA indicated a significant difference in adjusted means in metacognitive bias across Google access groups, allowing for the rejection of the null hypothesis. This indicates that even after controlling for epistemic curiosity, there was significantly greater overconfidence with participants who were granted access to Google on a practice activity prior to taking a general knowledge assessment. The relatively large effect size provides further evidence of the impact of Google on metacognitive bias. The implications of these findings are discussed in Chapter 5.

CHAPTER FIVE: CONCLUSIONS

Overview

Chapter Five will begin with a brief review of the purpose of the study, as well as the prior literature, which will frame the coming discussion of the results. Next, implications of this study's findings will be addressed, including potential limitations and generalizability of those research findings. Finally, this conclusion of the chapter will introduce recommendations for future research.

Discussion

The purpose of this experimental, posttest-only control-group study was to determine if there were differences in levels of metacognitive bias between those who do and do not use Google on a practice activity prior to the administration of a general knowledge test, when controlling for epistemic curiosity. The researcher utilized Litman and Spielberger's 2003 Epistemic Curiosity Scale to derive summated curiosity scores, operationalized as an intrinsic, personality construct. Epistemic curiosity subsequently served as the covariate. Metacognitive bias, that is, overconfidence or underconfidence, was derived via the signed difference between participants' predicted score on a general knowledge assessment and their actual score. The higher the bias score a participant received, the greater was the overconfidence. This bias score served as the dependent variable. The independent variable was Google access, with the control group not being allowed access to Google during the practice activity, and the experimental group being allowed to use Google on the practice activity to *confirm* answers. Items for both the practice activity and the general knowledge assessment were derived from Tauber et al.'s (2013) re-norming of Nelson and Narens' 1980 general knowledge norms. Both instruments, Litman and Spielberger's 2003 Epistemic Curiosity Scale, and Nelson and Naren's 1980 general knowledge norms, have been used ubiquitously in prior studies, and have been repeatedly validated.

For the research question, the researcher's intent was to determine if any Google-induced increase in overconfidence would still be demonstrated after controlling for epistemic curiosity. This focus stemmed from two primary purposes. The first is that while there exists a significant body of research on curiosity, curiosity constructs, and the internet's potential impact on metacognitive accuracy, there is sparse literature connecting these domains. Fisher et al. (2021) called for the examination of the impact of individual differences on metacognitive bias. Epistemic curiosity, with an impressive collection of literature suggesting its importance in deeper learning and metacognitive accuracy, would appear to be a prime candidate to serve as such a variable (Binu et al., 2020; Cho & Woodward, 2018; Hardy et al., 2017).

Further, Metcalfe et al. (2020) posited that prior knowledge and metacognitive accuracy are prerequisites to curiosity since one cannot fill a knowledge gap one does not know exists. Flanagin & Lew (2022) called for further research into misattribution of external knowledge as internal knowledge, specifically within web-based environments. The second primary motivation behind the selection of this research question was to examine the possibility that personality constructs or characteristics can mitigate or moderate potentially negative impacts on prior knowledge and metacognitive accuracy. Further, this study's findings represent a meaningful exploration of the role of prior knowledge and cognitive schematic structures within the theoretical framework of constructivism. Foundational constructivist theorists place a remarkable value on prior knowledge, since such knowledge is viewed as the foundation for future learning (Ausubel, 1962; Çakır, 2008, & Piaget, 1960). If knowledge misattribution and overconfidence elicited by Google is as pronounced as prior research and the current study suggested, internet search engines pose a severe pedagogical risk within the constructivist paradigm.

The findings of this study support the extant literature that Google access appears to have a significant, deleterious impact on individuals' metacognitive accuracy. Dunn et al. (2021), Fisher at al. (2021), Stone and Storm (2021), Hamilton and Yao (2018a), and Storm et al. (2016) have provided a strong basis for the notion that access to the internet and internet search engines create a legitimate risk of misattributing external knowledge, found online, with one's own internal knowledge. Ward termed the difficulty in discerning internal from external knowledge as "knowledge ambiguity" (2021, p. 5). Within the same study, Ward also established that Google use is associated with greater self-reported confidence in internal knowledge, independent of any analysis of task-specific metacognitive bias. The findings of this study similarly evince the impact of Google on confidence, even before analyzing the relative accuracy of such confidence. Hamilton and Yao found that "individuals misattribute outcomes and characteristics of technology to the self while judging their own knowledge" (2018a, p. 266). This study's large effect size of Google access on overconfidence resoundingly supports such propositions in prior literature.

Sloman and Rabb (2016) reported similarly significant metacognitive misattribution when individuals gain access to information they perceive as being from experts. Subsequently, this study's findings may be suggestive of not only the bias-inducing effects of Google use, but the de facto expertise Google users grant to information found via the search engine, with or without proper vetting of the source. The level of metacognitive bias attributable to Google access within this study support the notion proposed by Bhatt and MacKenzie (2019) that individuals increasingly view the web as an extension of themselves. The effect size of Google access on metacognitive bias found in the current study aligns with the proposition by Firth et. al.

that "it is becoming clear that the Internet actually presents something entirely novel and distinct from previous transactive memory systems" (2019, p. 124).

These results are also suggestive of the vulnerability of the trait model of curiosity. If curiosity is an inbuilt trait or intrinsic personality characteristic, such as introversion or extraversion, and curiosity necessitates accurately understanding gaps in one's knowledge, it might be expected that greater levels of trait curiosity would moderate metacognitive bias elicited by Google access. The results of this study appear to emphatically preclude such a hypothesis, potentially suggesting that curiosity is better understood as a fluid, dynamic state brought about by temporary gaps in knowledge, as proposed by Murayama et al. (2019) and Schutte and Malouff (2019). Such fluid states are easily closed by the efficiency and fluency of Google. Litman et. al. (2005) argued that one's *feeling-of-knowing* is negatively correlated with epistemic curiosity, which would suggest that the greater the epistemic curiosity, the more diminished that individual's confidence. This study's findings do not support that assertion since significant differences in metacognitive bias survived statistical controls for curiosity.

Tip-of-the-tongue states are cognitive states of intense curiosity elicited by the perception that one knows the answer to a question but is at the cusp of finding it in his or her memory (Metcalfe et al., 2020). Because participants in the experimental group of this study were allowed to use Google to *confirm* their answers, participants' tip-of-the-tongue states could be easily and instantly satiated, diminishing curiosity while also providing users with a plausible notion that they did, in fact, know an answer just out of their cognitive reach. More broadly, these results appear to hamper the proposition that individual differences can meaningfully mitigate the internet's propensity to creating overconfidence or other iterations of metacognitive miscalibration. Such findings add increased importance to the proposition that the implementation of reflective tasks can improve metacognitive accuracy (Salovich & Rapp, 2021; van Laer & Elen, 2019). Within this study, it becomes clear that Google as a pedagogical tool does not appear to induce such reflection.

The theoretical framework of this study, constructivism, requires a high value be placed on prior knowledge. Within the constructivist paradigm, what we already know is paramount in encoding that which we do not yet know. It is through this lens that the results of this study take on a heightened importance. From the constructivist perspective, there exists a threshold of prior knowledge and metacognitive accuracy as a perquisite for curiosity (Metcalfe et al., 2020). This perspective is a reasonable inference insofar as one may assume that curiosity, the desire to fill knowledge gaps, is necessarily bound by what the individual accurately perceives about their prior knowledge. An individual does not have a desire to fill a knowledge gap he or she does not think exists. This dual deficit of sufficient prior knowledge and metacognitive calibration thus stunts individuals' selection of attention due to inhibition of disequilibrium (Smith et al., 2021). Simply put, in order to learn, one must register the tension between what one knows and what one has yet to know, a potentially impossible task if Google has thwarted one's ability to accurately gauge internal knowledge. This study's findings, with participants' low general knowledge scores and even worse metacognitive bias scores, support such a stance, and highlight the dangers of internet-induced overconfidence on schematic learning processes, as Google places no responsibility on users to actually encode and retain information (Wegner, 2013).

This study's findings also appear to be supportive of the notion that the use of Google does not allow for the desirable difficulty required for learning (Bjork & Bjork, 2020), highlighting not only the impact of Google on cognition, but the pedagogical underpinnings of that impact. Despite modern education's acceptance and even reliance on the internet as a research tool, most web users do not initiate online searches to gain information, but instead seek to complete a task (Weinreich et al., 2008).

The rejection of the null hypothesis thus supports prior studies' findings that internet searches elicit significant overconfidence in one's own internal knowledge, likely due to knowledge misattribution. This study does not, however, appear to support the notion that personal characteristics, such as curiosity, can moderate metacognitive bias. Finally, the current study is unable to support the trait model of curiosity.

Implications

The findings of this study provide further evidence that the fluency of Google leads individuals to misattribute the internet's collective knowledge for their own, eliciting significant overconfidence in personal knowledge stores. This detrimental impact on metacognitive accuracy represents a significant pedagogical hurdle. It has been a mantra of students for generations to question why they need to know something or when they will ever use some new content. In the age of Google, a more pressing question may now very well be, "Why do I need to know *anything*?" Because students and adults alike increasingly offload cognition onto the internet, there is arguably less leverage than ever before to motivate students to internally encode any new knowledge.

Further, the evinced negative impacts on metacognitive accuracy by the internet means that even students who ostensibly do value internal knowledge and appear to be relatively curious nonetheless significantly overestimate what they know and the depth with which they know it. Without a clear, research-based vision for how to moderate the impact the internet has on our cognitive selves, there exists an escalating risk of a perpetual feedback loop in which individuals' lack of prior knowledge, and the attendant lack of recognition of this deficit,creates still larger deficits in prior, internal knowledge. As such, these findings hold significant importance pertaining to best practices within the classroom. As of the writing of this study, artificial intelligence has exploded onto the informational technology space. AI now has the capacity to create products written in the style and voice of an individual student, potentially expanding our collective exposure to metacognitive inaccuracy and knowledge misattribution (Ventayen, 2023). We now inhabit a technological and intellectual zeitgeist wherein our reliance upon powerful information technology has few limitations.

In concert with the rising tide of metacognitive overconfidence comes a spate of societal threats. In the absence of an accurate accounting of our own knowledge and skills, our trust in and reliance upon social institutions may already be in the process of decaying. Societies have historically leaned on social institutions, such as science, news media, government, the church, and their respective expertise, to provide answers we do not know. Without an accurate notion of both our knowledge deficits and the value of knowledge itself, these institutions may appear less valuable and less trustworthy (Motta et al., 2018). Institutional trust has dropped precipitously throughout many western nations the last five years (Perry, 2021). Distrust in these important institutions damage social relationships and erodes the fabric of society (Van Prooijen et al., 2022). Further, without trusted institutions serving to adjudicate difficult social and political questions or dilemmas, the polarization which has run rampant throughout the United States and other western democracies may continue to flourish (Anson, 2018; Yu et al., 2024). It is arguable that there has never been a more important time to enter into the public sphere with humility before informational technology, an acknowledgment that we are vulnerable to significant overconfidence, and a readiness to admit that there is much we must still learn.

Never before has there been so much information at our fingertips, accessible on a whim and retrievable in seconds. Paradoxically, there exists good reason to suspect that it has never been harder for us to truly maintain knowledge. The human brain is a wonder of creation; it is a biological supercomputer and a pattern-recognition machine. It is, however, rife with cognitive biases. Most of these biases are typically benign. The unrivaled and unprecedented power of the internet, however, seemingly has the ability to leverage our cognitive architecture's vulnerabilities to an unparalleled and dangerous extent. In an environment in which the rate of knowledge accumulation and diffusion approaches a kind of informational singularity, the association our brains make with the ease and fluency of information access and our actual comprehension of that information is a legitimate threat.

There exists an exploding body of research indicating that the internet, and the internet's search engines in particular, tap into the premium the brain places on speed of information retrieval, to such an extent that it becomes difficult to distinguish between what one knows internally, or what one has merely encountered externally. In turn, metacognitive bias—cognitive overconfidence—proliferates. If constructivism and the value it places on anchoring new learning into prior learning is valid, then Google-elicited metacognitive bias could potentially create, or could already be creating, a cycle in which students accumulate larger and larger deficits in prior knowledge and are none the wiser of it. One cannot remedy a lack of knowledge that itself remains unacknowledged.

The results of the current study provide an opportunity to further examine the relationship between the informational technologies we hold dear and the cognitive lives we increasingly take for granted. It is perhaps unsurprising that the current study found, comporting with prior research, that the mere act of using a search engine produces overconfidence in one's cognitive abilities. It is alarming, however, that this study produced virtually no evidence that innate curiosity overcomes such overconfidence and should spur educational researchers to examine how often students are asked to engage in metacognitive reflection, are trained in metacognitive strategies, or are assessed for metacognitive accuracy. Similarly, there is an opportunity to further investigate what individual psychological or cognitive characteristics can potentially be leveraged to moderate the internet's influence on our metacognition. Finally, research should focus on what constitutes best practices with the abundant and powerful technologies at our disposal, particularly with regard to how those best practices can protect our ability and willingness to truly learn.

Limitations

While this study utilized a strong, true experimental design with random selection and random assignment, the generalizability of these findings nonetheless has limitations. First, both of the school sites selected were within the same school district in the upstate of South Carolina. Both schools had significantly lower than average poverty indexes than many surrounding districts, and it is yet unknown the extent to which socioeconomic factors may affect the metacognitive bias elicited by Google access. Similarly, all students at both schools participated in a 1:1 Chromebook initiative for most of their academic careers. Again, it is not known the extent to which the long-term exposure to these devices and the institutional reliance on these devices by districts impact these findings. Students who have long associated formal education with internet-connected devices could very well have developed coping mechanisms against metacognitive bias that other students have not. Conversely, it could be that students from more impoverished areas who have less unrestricted Google access at school have come to rely less on the internet, placing more value on and trust in institutions.

Further hampering wide generalizability is the demographic breakdown of the selected schools. The samples taken were overwhelmingly White and middle class. While the samples were representative of the broader population of the county, more research must be conducted to determine the extent to which socioeconomic status, ethnicity/race, and age impact metacognitive bias. The age of participants in this study ranged from 15-17, and the extent to which these findings may be generalized to both younger and older samples is not yet known.

Finally, because curiosity remains a broadly defined and inconsistently operationalized construct, it may be that more research is needed to create more robust instruments to quantify curiosity and differentiate among its types. This study is a relatively novel undertaking in that it operationalized curiosity as a personality trait for use as a covariate. The appropriateness of this method and refinements to such use will only be borne out by future studies. Similarly, the general knowledge norms utilized in this study were created in 1980 and may not necessarily reflect the collective body of general knowledge in the year 2024, particularly in the population sampled.

Recommendations for Future Research

The researcher recommends the following for future research:

1. Conduct similar studies throughout various age ranges, with differing socioeconomic statuses and demographic breakdowns, in order to create more generalizable findings.
2. Conduct a qualitative study, perhaps within a grounded study design, in which students' perceptions of their own knowledge, the value of internal knowledge, and how those perceptions are informed by use of Google are integrated through interviews and observation.
3. Conduct correlational research aimed at identifying and quantifying the relationship

between duration and frequency of Google exposure with metacognitive bias.

4. Design a study in which one class disallows the use of Google within the instructional setting, one class provides limited and directed use of Google within the instructional setting, and one class provides unlimited use of Google within the instructional setting. At the conclusion of the interval, the researcher may compare the mean metacognitive accuracy of all groups.
5. Design a study in which one class employs intentional training in metacognitive monitoring to students, and one class does not. At the conclusion of the interval, the procedures followed in the current study may be used to determine if long-term training in metacognitive monitoring can moderate the impact of Google on metacognitive bias.
6. Conduct a correlational study to determine if there is an association between metacognitive bias and negative political partisanship.
7. Design a study in which the mean metacognitive bias of students in 1:1 device programs are compared to that of students not in a 1:1 device program.
8. Conduct a correlational study to determine if there is an association between metacognitive bias and institutional distrust.

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APPENDIX A

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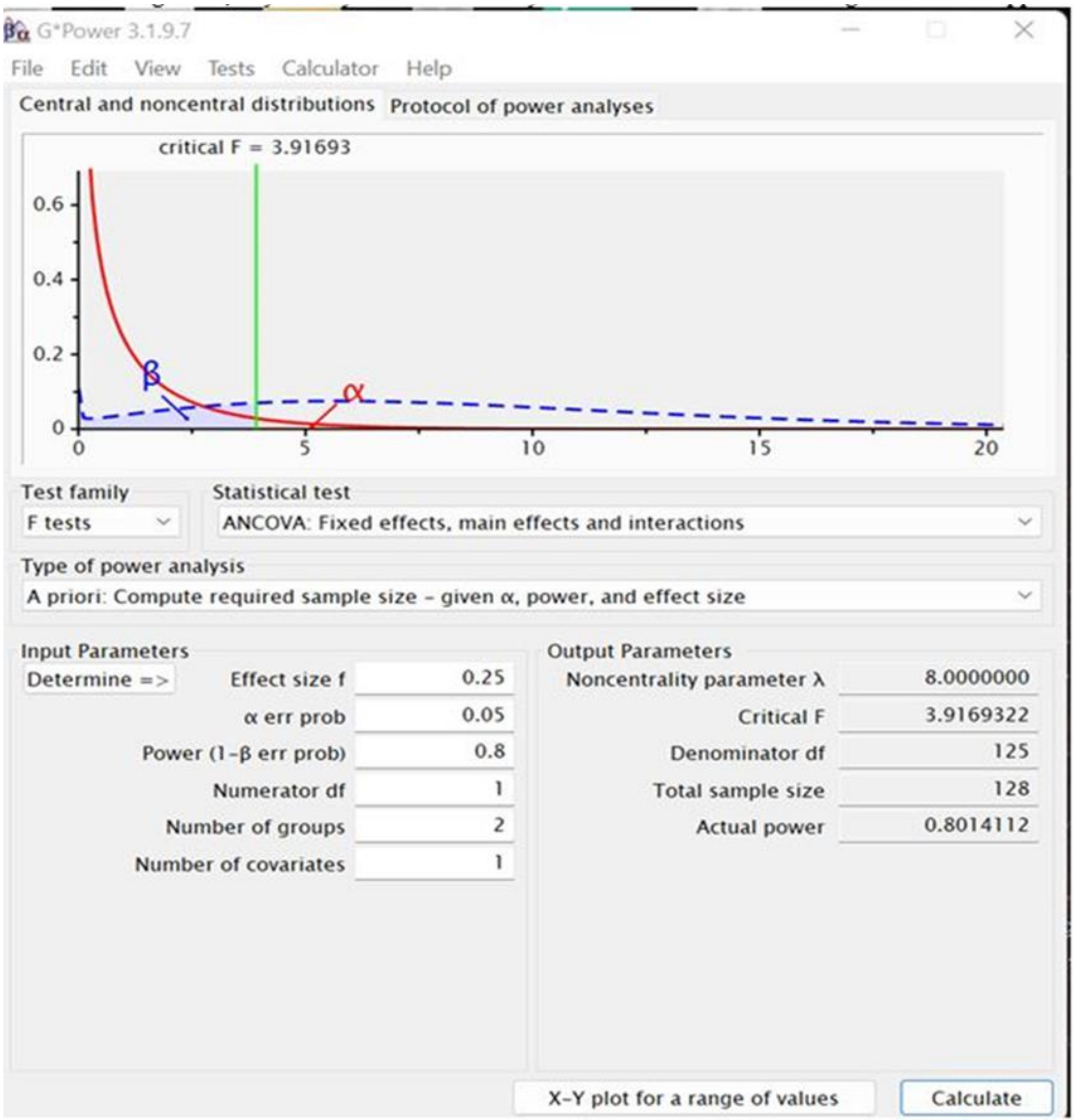
APPENDIX C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ANCOVA: Fixed effects, main effects and interactions
Type of power analysis
A priori: Compute required sample size – given α, power, and effect size
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Number of groups 2
Number of covariates 1
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Noncentrality parameter λ 8.0000000
Critical F 3.9169322
Denominator df 125
Total sample size 128
Actual power 0.8014112
X-Y plot for a range of values
Calculate

APPENDIX D

Proctor Script (Control Group)

Introduction

"Good morning. Thank you for your participation in today's study. Please examine the ticket you were provided upon entrance into the classroom and verify that your test ticket number corresponds with the number on your computer station. If you are not sure, raise your hand, and I will be happy to help you.

Today you will be taking three brief assessments: a curiosity survey, a general knowledge practice assessment, and a general knowledge assessment. These assessments are not timed. It is important that you do your best, and that you look at your computer screen only. You may find some items easy, and others more difficult. Take your time and thoughtfully answer all questions you can. If at any point you have a question or concern about accessing materials or how to submit an answer, raise your hand. Upon completion of today's study, five participants will be drawn at random to receive a $50 Visa gift card."

Epistemic Curiosity Scale

"Take a look at your computer screen. You should see at the top an Assessment titled 'Curiosity Survey.' Click 'Start Survey,' and then await further instructions. You should now see a brief description of the survey. Read along silently as I read aloud.

'A number of statements that people use to describe themselves are given below. Read each statement and then select the appropriate response using the scale below to indicate how you generally feel. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer that seems to describe how you generally feel.'

Are there any questions on how to complete the survey? Once you have completed the survey, you will be sent back to the study's homepage. Do not proceed any further or click any other links. You may now click 'next,' and begin."

General Knowledge Practice Assessment

"You will now take a 10-item general knowledge practice activity. These questions have been given hundreds of times in prior studies. On average, each question in this activity was answered correctly by approximately 50% of prior participants. You will type your answers into each answer field. Do your best to spell answers correctly, but know that an incorrectly spelled item will not necessarily disqualify your answer. If you do not know the answer, guess. Do not leave answer fields blank.

After you have typed your response, you will click ‘submit,’ which will move you on to the next question. Once you have clicked submit you will not be able to go back to prior questions. You may not use any other website during this assessment. Answers must be your own. Once you have completed the assessment, you will again be redirected to the study home page. Do not continue to any other section or utilize any other applications on the computer. Are there any questions? Look at your computer screen and click the link for ‘Practice Assessment,’ and begin.”

Break

“You will now be provided a ten minute break, during which time you may use the restroom, stretch, or get water. Please refrain from discussing test items with other participants. The time is now __:__. You must be back in the classroom by __:__.”

General Knowledge Assessment

“You will now take a 20-item general knowledge assessment of similar difficulty to the pre-test you were just administered. You will complete the assessment the same way you did the practice assessment. On the first screen, you will be prompted to predict what percentage of the questions you believe you will answer correctly. Provide this answer in percentage form. For instance, if your prediction is 80%, type ‘80 %’ instead of ‘.80.’ Once you’ve completed your prediction, you may click ‘next’ and complete your test. Do not leave any questions unanswered. You are not penalized for incorrect guesses. You may not use Google or any external source for this assessment. Once you are finished, please remain quietly seated. Are there any questions? You may begin.”

Completion

“Thank you for your participation in today’s study. The five winners of the drawing will be contacted within 10 business days to receive your gift card. You may now return to class.”

Proctor Script (Experimental Group)

Introduction

"Good morning. Thank you for your participation in today's study. Please examine the ticket you were provided upon entrance into the classroom and verify that your test ticket number corresponds with the number on your computer station. If you are not sure, raise your hand, and I will be happy to help you.

Today you will be taking three brief assessments: a curiosity survey, a general knowledge practice assessment, and a general knowledge assessment. These assessments are not timed. It is important that you do your best, and that you look at your computer screen only. You may find some items easy, and others more difficult. Take your time and thoughtfully answer all questions you can. If at any point you have a question or concern about accessing materials or how to submit an answer, raise your hand. Upon completion of today's study, five participants will be drawn at random to receive a $50 Visa gift card."

Epistemic Curiosity Scale

"Take a look at your computer screen. You should see at the top an Assessment titled 'Curiosity Survey.' Click 'Start Survey,' and then await further instructions. You should now see a brief description of the survey. Read along silently as I read aloud.

'A number of statements that people use to describe themselves are given below. Read each statement and then select the appropriate response using the scale below to indicate how you generally feel. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer that seems to describe how you generally feel.'

Are there any questions on how to complete the survey? Once you have completed the survey, you will be sent back to the study's homepage. Do not proceed any further or click any other links. You may now click 'next,' and begin."

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After you have typed your response, you will click 'submit,' which will move you on to the next question. Once you have clicked submit you will not be able to go back to prior questions. Do your best to answer these questions using your own knowledge. Take your time and search your memory as necessary. If you need additional support, you may use a Google search with the additional browser tab provided to verify your answer. Once you have completed the assessment, you will again be redirected to the study home page. Do not continue to any other section or utilize any other applications on the computer. Are there any questions? Look at your computer screen and click the link for 'Practice Assessment,' and begin."

Break

"You will now be provided a ten minute break, during which time you may use the restroom, stretch, or get water. Please refrain from discussing test items with other participants. The time is now __:__. You must be back in the classroom by __:__."

While participants are out of the classroom, the proctor will exit out of any additional browser tabs on each computer.

General Knowledge Assessment

"You will now take a 20-item general knowledge assessment of similar difficulty to the pre-test you were just administered. You will complete the assessment the same way you did the practice assessment. On the first screen, you will be prompted to predict what percentage of the questions you believe you will answer correctly. Provide this answer in percentage form. For instance, if your prediction is 80%, type '80 %' instead of '.80.' Once you've completed your prediction, you may click 'next' and complete your test. Do not leave any questions unanswered. You are not penalized for incorrect guesses. You may not use Google or any external source for this assessment. Once you are finished, please remain quietly seated. Are there any questions? You may begin."

The proctor should circulate the testing site to ensure that no participants are using any other website. Participants who do not follow protocol should be allowed to finish, but the proctor should note the computer station number and participant's name to disqualify their data from analysis.

Completion

"Thank you for your participation in today's study. The five winners of the drawing will be contacted within ten business days to receive their gift card. You may now return to class."

APPENDIX E

Parental Opt-Out

Title of the Project: *Constructivism, Curiosity, and Metacognitive Bias in the Age of Google*
Principal Investigator: Matthew Moore, Doctoral Candidate, School of Education, Liberty University

Invitation to be Part of a Research Study

Your child is invited to participate in a research study. To participate, he or she must be between 15 and 17 years old and able to independently navigate a web-based assessment. Taking part in this research project is voluntary.

Please take time to read this entire form and ask questions before deciding whether to allow your child to take part in this research project.

What is the study about and why are we doing it?

The purpose of my research is to investigate the extent to which Google use leads to academic or cognitive overconfidence in adolescents. It further investigates whether an individual's curiosity affects this overconfidence.

What will participants be asked to do in this study?

If you agree to allow your child to be in this study, I will ask him or her to do the following:

1. Complete a 10 item survey measuring their tendencies towards curiosity. (5 minutes)
2. Complete a 10 item practice activity on general knowledge. Half of the participants will be randomly assigned to the control group, in which they must complete the practice assessment without any external help. The other half of the participants will be assigned to the experimental group, and will be allowed access to Google to confirm answers to the practice assessment. (10-15 minutes)
3. Predict their score on a general knowledge assessment of similar difficulty. (1 minute)
4. Complete a 20 item general knowledge assessment of similar difficulty to the practice activity. (20-25 minutes)

How could participants or others benefit from this study?

Participants should not expect to receive a direct benefit from taking part in this study, aside from receiving their personal scores on the general knowledge assessment and information on their own cognitive accuracy.

Benefits to society include providing expanded insight into the influence Google searches may have on the accuracy of individuals' assessment of their own knowledge or ability, and the extent to which curiosity moderates that influence.

What risks might participants experience from being in this study?

The expected risks from participating in this study are minimal, which means they are equal to the risks your child would encounter in everyday life.

How will personal information be protected?

The records of this study will be kept private. Research records will be stored securely, and only the researcher and faculty sponsor will have access to the records.

- Participant responses will be anonymous.
- Data will be stored on a password-locked computer. After three years, all electronic records will be deleted and all hardcopy records will be shredded.

How will participants be compensated for being part of the study?

Participants may be compensated for participating in this study. At the conclusion of the study, five participants will be randomly selected to receive a $50 Visa gift card. Any participant who chooses to withdraw from the study after beginning but before completing all study procedures will receive a $10 Chick-fil-A gift card.

Is study participation voluntary?

Participation in this study is voluntary. Your decision whether to allow your child to participate will not affect your or his or her current or future relations with Liberty University or your high school. If you decide to allow your child to participate, he or she is free to not answer any question or withdraw at any time prior to submitting the surveys without affecting those relationships.

What should be done if a participant wishes to withdraw from the study?

If you choose to withdraw your child from the study or your child chooses to withdraw, please have him or her exit the survey and close his or her browser. Inform the researcher that your child wishes to discontinue his or her participation, and your child should not submit the study materials. Your child's responses will not be recorded or included in the study.

Whom do you contact if you have questions or concerns about the study?

The researcher conducting this study is Matthew Moore. You may ask any questions you have now. If you have questions later, **you are encouraged** to contact him at [redacted]. You may also contact the researcher's faculty sponsor, Dr. Michelle Barthlow, at [redacted]

Whom do you contact if you have questions about rights as a research participant?

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, **you are encouraged** to contact the IRB. Our physical address is Institutional Review Board, 1971 University Blvd., Green Hall Ste. 2845, Lynchburg, VA, 24515; our phone number is 434-592-5530, and our email address is irb@liberty.edu.

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Consent/Opt-Out

If you would prefer that your child NOT PARTICIPATE in this study, please sign this document, and return it to your child's school office by 2/2/24.

____

Printed Child's/Student's Name

____

Parent/Guardian's Signature Date

APPENDIX F

January 12th, 2024

Dear Student,

As a doctoral candidate in the School of Education at Liberty University, I am conducting research in order to satisfy degree requirements and to better understand an issue that has become increasingly relevant to young people inside and outside of the classroom. The purpose of my research is to investigate the extent to which Google use leads to academic or cognitive overconfidence in adolescents. I am writing you to inform you that you have been selected to participate in this study.

Participants must be between the ages of 15 and 17 and capable of independently navigating two brief, web-based assessments. Participants will be split into 2 groups, half will be assigned to the control group, in which they must complete the practice assessment without any external help, and the other half will be assigned to the experimental group, and will be allowed access to Google to confirm answers. Participants will be asked to complete a 10 item survey quantifying your level of curiosity, as well as a brief practice assessment on general knowledge, before completing a 20 item general knowledge assessment of similar difficulty. It should take approximately 45 minutes to complete the procedures listed. Participation will be completely anonymous, and no personal, identifying information will be collected.

A parental consent form has been mailed home. This document contains additional information about my research. **Parents should sign and return the consent document to the front office if you *DO NOT* wish your child to participate.**

Five participants will be randomly selected to receive a $50 Visa gift card.

Sincerely,

[redacted]

Matthew Moore
Principal
Pendleton High School
864-403-2102
mmoore@anderson4.org

APPENDIX G

Date: 1-21-2024

IRB #: IRB-FY23-24-279
Title: CONSTRUCTIVISM, CURIOSITY, AND METACOGNITIVE BIAS IN THE AGE OF GOOGLE
Creation Date: 8-17-2023
End Date:
Status: Approved
Principal Investigator: Matthew Moore
Review Board: Research Ethics Office
Sponsor:

Study History

Submission Type	Initial	Review Type	Expedited	Decision	Approved

Key Study Contacts

Member	Matthew Moore	Role	Principal Investigator	Contact	[redacted]
Member	Matthew Moore	Role	Primary Contact	Contact	[redacted]
Member	Michelle Barthlow	Role	Co-Principal Investigator	Contact	[redacted]

APPENDIX H

LIBERTY UNIVERSITY.
INSTITUTIONAL REVIEW BOARD

December 4, 2023

Matthew Moore
Michelle Barthlow

Re: IRB Approval - IRB-FY23-24-279 CONSTRUCTIVISM, CURIOSITY, AND METACOGNITIVE BIAS IN THE AGE OF GOOGLE

Dear Matthew Moore, Michelle Barthlow,

We are pleased to inform you that your study has been approved by the Liberty University Institutional Review Board (IRB). This approval is extended to you for one year from the following date: December 4, 2023. If you need to make changes to the methodology as it pertains to human subjects, you must submit a modification to the IRB. Modifications can be completed through your Cayuse IRB account.

Your study falls under the expedited review category (45 CFR 46.110), which is applicable to specific, minimal risk studies and minor changes to approved studies for the following reason(s):

7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies. (NOTE: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(2) and (b)(3). This listing refers only to research that is not exempt.)

For a PDF of your approval letter, click on your study number in the My Studies card on your Cayuse dashboard. Next, click the Submissions bar beside the Study Details bar on the Study Details page. Finally, click Initial under Submission Type and choose the Letters tab toward the bottom of the Submission Details page. Your stamped consent form(s) and final versions of your study documents can be found on the same page under the Attachments tab. Your stamped consent form(s) should be copied and used to gain the consent of your research participants. If you plan to provide your consent information electronically, the contents of the attached consent document(s) should be made available without alteration.

Thank you for your cooperation with the IRB, and we wish you well with your research project.

Sincerely,

G. Michele Baker, PhD, CIP
Administrative Chair
Research Ethics Office