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In answering the question “Where is art?”, this dissertation points towards toward virtual art gallery tools as an important context for study in the psychology of arts and aesthetics. Across three ordinal stages, (1) Developing the Open Gallery for Arts Research, (2) Expanding the OGAR Toolset and Research Program, and (3) Leveraging OGAR’s Capabilities to Enrich the Field, this work describes the development and research expansion of a framework for studying virtual art gallery experiences that aligns with open source and open science aims. After discussing this program of research, these findings are integrated to reveal new discourse on the state of the field. Throughout this section, I elaborate on outstanding questions about the use of virtual galleries in psychology of art research, insights into emerging opportunities for topic growth, and remaining conceptual challenges facing the adoption of virtual galleries in psychology of arts research. Thus far, it seems that this area of research must overcome some challenges in its perception in order to make its fullest contribution to the field. Altogether, however, virtual gallery tools reveal the shared and surprising psychology of digital interactions with art. This program of research and similar frameworks are poised to make significant progress in the psychology of arts and aesthetics, especially when considered as a companion tool for diverse methodologies.

THE PSYCHOLOGY OF VIRTUAL ART GALLERY EXPERIENCES

by

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DEDICATION

To those that I love the most deeply, thank you for supporting my most exciting work of art yet—even if it isn’t as pretty to look at.

APPROVAL PAGE

This dissertation written by Rebekah M. Rodriguez has been approved by the following committee of the Faculty of The Graduate School at The University of North Carolina at Greensboro.

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To Paul, Katherine, Div 10, and my committee, I express my gratitude. While I never knew zoom meetings could be so inspiring, I am nonetheless glad to have had the pleasure of knowing you in person. Some virtual experiences just can't compete with the real thing.

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CHAPTER I: INTEGRATED INTRODUCTION

Where is art? Much less infamous than its interrogative sister, “What is art?”, most people would reply, “in a museum or gallery,” or they might quip, “wherever you hang the canvas,” or even a vague and cagey “everywhere.” They point in the direction of beautiful and surprising objects—objects with which they have profound psychological ties. But what happens when art doesn’t have a set of map coordinates? If you ask Google for the location of Leonardo da Vinci’s *Mona Lisa*, the search engine will happily provide the latitude and longitude for the Louvre Museum in Paris, France: 48° 51′ 40″ N, 2° 20′ 09″ E. But is it possible to experience the famous da Vinci painting without traveling to this spot and standing among the gaping crowd of visitors encircling the canvas?

In his essays on the philosophical nature of art, Walter Benjamin famously commented on the status of art in an age of increasing reproducibility: “Mechanical reproduction emancipates the work of art from its parasitical dependence on ritual” (Benjamin, 1968, p. 224). Perhaps more than the mechanical reproduction of art, this age is driven by the digital reproduction and dissemination of art. Technology has had a transformative effect on art and culture and the nature of our engagement with it. Digital art and virtual art environments in which to “hang” it are a firmly integrated part of cultural experience today. These spaces are pushing out the edges that cultural institutions can reach and have achieved substantial adoption by museums and art viewers around the world in recent years. Given how commonplace these tools have become, however, we know little about the psychological nature of digital engagement with art. In particular, the present work discusses the psychology of the virtual art gallery visit and the potential of virtual gallery tools to guide the future of research on art and aesthetics.

Throughout the rest of this document, I describe growth in the psychological study of virtual art gallery experiences, grounded in the development and research expansion of the Open Gallery for Arts Research (OGAR) project—a set of tools for designing and studying visits to virtual art galleries. After a bit of background on the psychology of art and aesthetics, this discussion is organized in three ordinal stages: (1) Developing the Open Gallery for Arts Research, (2) Expanding the OGAR Toolset and Research Program, and (3) Leveraging OGAR's Capabilities to Enrich the Field. In discussing this program of research, I will integrate these findings to provide some discourse on the state of the field, outstanding questions about the use of virtual galleries in psychology of art research, insights into emerging opportunities for topic growth, and remaining conceptual challenges facing the adoption of virtual galleries in psychology of arts research.

Scholarly Context on the Psychology of Virtual Art Galleries

In answering the question of where we can find art, it is useful to know that the origin of the psychology of art and aesthetics is older than our modern conceptions of what art is. Often traced back to a seminal work by Gustav Fechner, *Vorschule der* Ästhetik (Elementary Aesthetics; Fechner, 1876), this area of study predates conceptual art and Marcel Duchamp's ready-made art, and only narrowly postdates what is often considered the first modern painting, *Luncheon on the Grass*, by *Édouard* Manet in 1863 (Arnason & Prather, 1998). It would be nearly 100 years, however, before the psychology of art and aesthetics would gain wider interest among researchers.

This turning point came with the introduction of Daniel Berlyne's (1971) psychobiological theory of aesthetics, which focused on arousal as a means by which we access reward and build preference for stimuli. Although some aspects of Berlyne's ideas had conceptual limitations (see Silvia, 2005 for a review of and appraisal-based responses to these), he was right in calling his work the "new experimental aesthetics." His emphasis on tightly controlled laboratory-based experimentation used cognitive and behavioral science methodology that is still foregrounded in the psychology of art and aesthetics today (Nadal & Ureña, 2021).

Contemporary research in the psychology of art and aesthetics is largely lab-based—using tried-and-true behavioral experiments, neuroimaging methodologies, and statistical analysis approaches to answer big questions about how we interact with art, experience beauty (and ugliness), and perceive the everyday world (Nadal & Vartanian, 2022). However, this field is as diverse as it is focused; it responds as much to applied problems as it does to looming conceptual and theoretical inquires.

A small, but well-respected, group of researchers in the psychology of art and aesthetics studies the psychology of the museum visit (Smith, 2014; Smith & Smith, 2020; Tinio et al., 2014). They find this work substantive to the field of art and aesthetics for a few key reasons. First, their work is important for reasons that all fieldwork is important: it provides greater ecological validity and generalizability, it allows for the examination of more complex and multifaceted behavior, and it is essential for developing psychological interventions that benefit the real-world. Second, they are interested in museums as a canonical context for art viewing. Places of art engagement are important to their communities, often providing a place of cultural engagement, leisure-based learning, and deeply personal reflection. In this sense, some psychological aspects of art viewing are quintessential to embodied, contextualized environments and simply have no parallel in lab settings. This makes the psychology of the museum visit substantive in the same way that we find school psychology or organizational psychology substantive (Smith, 2014).

But what does all this history have to do with the psychology of virtual galleries? The last two decades have seen the internet become ubiquitous in the West. With it came a proliferation of digital tools for art engagement coming from tech leaders and museums around the world (see, for example Google Arts and Culture Project, 2011; Proctor, 2011). Although, unlike digital contexts like social media (Keles et al., 2020) and online gaming platforms (Lee & Peng, 2006), these experiences have not received much study by psychologists. This is starting to change, however. Movement toward research in virtual galleries represents a new, digital epoch in psychological research on art that aims to reconcile its long-built heritage with interactive technologies that have reached a point of considerable impact on and integration with daily life. In tradition with the lab-based experimentalists and the museum-based field researchers that have built the psychology of art and aesthetics, this work contributes to this field's robust methodologies and considers a new context for substantive thought: the virtual art gallery. The questions posed in this dissertation can be seen as both potential solutions to some of the problems confronting traditional arts and aesthetics research as well as forays into a contemporary context for art viewing that is unique and important in its own right.

Stage 1: Developing the Open Gallery for Arts Research

Early Conceptualization

In the spring of 2020, I spent most of my time alone on a futon in an abandoned dorm room with my failing laptop propped up on a side table that I used as a desk. I was an art student in the final semester of my undergraduate program, but my senior gallery show had been canceled and my art supplies were locked away in a studio building that I could no longer access as the outside world was engulfed in the COVID-19 pandemic. I was also newly accepted into a graduate program in psychology but unsure that I would ever get to pursue the art museum research that I had been hoping to do. With my debut gallery show canceled and my future prospects uncertain, my partner suggested that we while away the time with a software project—a virtual art gallery. Such galleries were getting big at the time; art museums and major tech companies across the globe were excited to unveil their latest projects to the masses of pandemic-isolating couch enthusiasts like me.

It was the first suggestion in months that had made me feel optimistic. And this optimism, perhaps born out of ignorance, kindled two key ideas. The first idea was to create an application that I could use to present my canceled show to a digital audience. This required building an application that was free, easy to change for curation, and that would run on my pitiful laptop. The second idea, developed a little later, was to create a tool that I could run a psychology study on. My eager graduate advisor, a self-proclaimed fan of "writing a lot," had already been reaching out to get to work and urged for planning around pandemic-related shut-downs. Needless to say, the first plan never came to fruition, but the second idea proved well-timed in the changing landscape of museum offerings and arts research.

Indeed, as many field studies in the psychology of arts stalled (see, for example, Rodriguez et al., 2021), museums were busy expanding their online presence with virtual offerings (International Council of Museums, 2023). With the unprecedented growth, there became a need to better understand the psychological nature of these experiences. At the same time, the field was experiencing a need for new tools and methods to grow the research. Virtual galleries, it turned out, were promising to fill both voids.

Development and Design Decisions: Promoting Open Source and Open Science

Coincidentally, the virtual gallery aims that would allow me to present my own gallery show were also important to the operations of behavioral researchers. Thus, retaining a low operating cost, prioritizing manipulability, and ensuring adequate performance on a wide variety of machines remained important cornerstones in the development of our virtual gallery, which we decided to name OGAR to reflect our new path towards research usability. Other choices, discussed below, emerged as the tool's development started to take form.

One of the biggest considerations driving design decisions for the OGAR project is the work's strong emphasis on promoting open-source software and open science aims. This effort started from the ground up with the choice to develop OGAR client and server tools using JavaScript and Python3, two widely-used open standard programming languages, respectively. Choosing programming tools with large, active user communities is foundational to promoting open-source initiatives, because it provides growing software projects with the best chance of adopting wide use and benefiting from community-based development contributions.

After initial software development was complete, source code and documentation for OGAR were made available on GitHub under the MIT license. GitHub is a popular software development and collaborative version control platform that has become well-known for hosting and distributing open-source projects. Once posted, a project can be downloaded by users, followed by people interested in receiving notifications about new releases or project news, and edited by community members to implement new features, fix problems, and more. Pairing the release of OGAR's source code with MIT licensing further enhances the open nature of the project, because it creates a copyright environment that is extremely permissive: "permission is granted, free of charge, to any person obtaining a copy of this Software...without restriction, including without limitation in the rights to use, copy, modify, merge, publish, distribute, sublicense, and/or sell copies of the Software," (Saltzer, 2020, p. 95).

Creating an open-source science tool like OGAR using open-source development options contributes to several principles that align with open science. Two major goals of open science are promoting wider access to scientific knowledge and increasing transparency and responsibility in the research process. As a research-oriented part of this process, preprints, data, figures, and analytic code for each of the OGAR-based projects used in this manuscript have been made available on Open Science Framework. Promoting the open-source nature of the OGAR software, however, makes this line of research truly "open." Open science ends wherever open access to the tools used to complete a line of research ends. Since OGAR tools are themselves open-source and free, it is easier for others to replicate and verify OGAR-based research, build on existing research, and reduce inequality in research resources. Weaving open-source software development and open science together make each effort stronger by contributing to project sustainability and building communities of researchers and developers.

Data-Driven Research and Reproducibility

Ensuring that research is data-driven and reproducible are central tenets of open science. When designing OGAR, great thought was put into making sure that the outputs of the tool are data-driven and reproducible. These design choices can be grouped broadly into supporting manipulability, enabling extensive data collection and recording, and producing accompanying data processing tooling.

Supporting Manipulability. When I became interested in virtual gallery tools, I noticed a dearth of flexibility and extensibility tools in widely-marketed options. Most tools limited the dimensions, features, or even the number of galleries that could be made (especially for free accounts). As annoying and inconvenient as this was to design a gallery of my own, this class of limitations is a deathblow to research usability. Robust science requires experimental manipulation to establish causal relationships where ethically possible. Supporting manipulability, therefore, became a major reason why developing this capability in OGAR is worthwhile to arts researchers. Manipulability in OGAR is bolstered by the gallery designer's freedom to vary aspects of the gallery floorplan, stimuli, and avatar attributes in an iterative manner, whereby an instance of OGAR can be saved and then changed incrementally according to the needs of the designer. Supporting iterative design increases manipulability while helping researchers maintain control in the gallery resources they create, thus avoiding a duplication of efforts. Researchers can build on previous work, refining their methods and exploring new questions as they go without having to start from scratch.

Data Collection and Recording. As I started this line of research into art experiences, I also noticed how hard data was to come by. In field settings, many data collection options suffered from low precision and were more difficult to implement than human-recording approaches. In virtual galleries designed for the end-user, however, data was commonly gate-kept by proprietors or not collected at all. As a result, another focus of OGAR became developing a sophisticated and comprehensive set of behavioral and environmental measurements to drive its research use toward being robust and informative.

To give an overview of OGAR's data collection framework, timestamped X and Y coordinate data, as well as pitch and yaw gaze data are collected from the participant every

200ms and recorded in a python server that runs concurrently with the gallery visit. This data can be contextualized given a "gallery definition" or a set of measurements that describe the static, pre-chosen layout of the gallery, location of stimuli, and avatar characteristics like eye height or maximum walking speed. Both sets of measurements—dynamic behavioral movements and static environmental choices—are scaled spatially in terms of meters and temporally in terms of seconds so that they can translated into "real-life" scales. Together, these measurements can be related or combined to arrive at meaningful descriptions of gallery behavior (discussed in depth later). Aside from these primary data streams, a third stream of collected data is dedicated to event and error reporting. Although not typically used in the research process, including this type of data aids in the development and improvement of OGAR tools, by allowing the project developers to better identify and correct problems with collected data.

Data Processing Tools. Finally, when exploring the literature on in-person museum or art gallery experiences, I noticed that when behavioral measures such as artwork viewing were recorded, there was very little standardization in how these data were captured or processed. To promote reproducibility in data collected with OGAR, additional preprocessing Python3 scripts were developed to take in raw collected gallery data and produce usable, minimally (but consistently) cleaned .csv files for further analysis. Giving researchers using the tool a common place to start increases efficiency and lowers the barriers to reproducibility. When data preprocessing tools are built into opensource projects like OGAR, not only is the scientific integrity of resulting research improved, but it opens an avenue for quality assurance in the tool such that the user community can help identify, review, and correct tool-based errors or limitations before it impacts published work.

Researcher Accessibility

Another pillar of open science is researcher accessibility. As a young researcher in a small lab with limited resources, locating tools and research paradigms that were accessible given my research constraints was an essential part of building my research profile. Given the complex interactions of resource availability and data collection opportunities, some situations are simply better suited for the affordances of virtual galleries, and some are better for blended or in-person work (for an overview of these situations, see Rodriguez-Boerwinkle & Silvia, 2023a). However, for situations where virtual gallery research is preferred, my colleagues and I wanted to be sure that OGAR tools provided an accessible experience for diverse researchers.

Our first step towards this aim was to design OGAR to be web-based and embeddable in common survey platforms such as Qualtrics. Designing OGAR as a web-based application promoted accessibility in several ways. First, researchers don't have to contend with the potential technical issues associated with software installation such as compatibility problems or poorly-matched system requirements. Second, data produced by OGAR is stored in an online server as opposed to a local device, so it is more resistant to loss than locally stored data. Third, the tool integrates well with other data collection services, such as Qualtrics, that researchers are already used to using to run their studies. This means that there is less of a learning curve associated with getting started using the OGAR toolkit. Finally, online data collection opens the participant pool to remote participants taking part in the study through collection platforms like Amazon MTurk or Prolific.co. This means that researchers can more easily access specific populations of interest or continue study recruitment when in-lab data collection is limited.

Our second step towards making OGAR more accessible to researchers was to make sure that it was an affordable option to use. In addition to making the tool itself free (similar tools can run a researcher thousands of dollars for just a few licenses or subscriptions), OGAR-based research paradigms do not require expensive eye or movement tracking equipment common in field studies. Typically, the only required cost to the researcher might be server space to collect incoming data, which may be available through some institutions. Other cost options are negotiable, as OGAR can be set up to work with a variety of tool integrations. This means that a researcher could opt for a free survey platform, for example, instead of Qualtrics, or a lab-based online data collection with student or community participants if paid online samples aren't viable.

At this early stage in OGAR's development, a few researcher accessibility problems remained: setting up online servers for data collection could be confusing and challenging for researchers lacking experience in this specific area, and gallery design, at this time, was completed by directly altering gallery definition code formatted as a JSON Object (Ecma-404, 2017). More development on the project would have to be done (discussed later) before improvements to these aspects of OGAR's research usability were improved.

Participant Usability

A third way that OGAR's development was inspired by the open science and open-source movements is its focus on participant usability. To optimize OGAR's usability for research participants, several choices were made regarding the control experience of the gallery client and the broader operating flexibility of the tool's architecture.

In terms of the participant experience within OGAR galleries, the virtual environment largely conforms to informal but common conventions used by similar applications such as computer-based videogames, learning tools, or social platforms that rely on 3D environmental graphics. This meant that navigation controls were set to the arrow keys or corresponding W, A, S, and D to move in each direction and that the gaze was controlled with a mouse, trackpad, or similar device. Movement throughout the space was smooth and continuous, and accelerated to a standard walking pace for control responsiveness that would be predictable and easy to understand for diverse computer users. To encourage a sense of immersion and continuity in the experience, naturalistic wall collision was implemented to gently 'bump' visitors off walls that they run into. The screen aspect ratio was set to 16:9 and the visual refresh rate was coded to be device dependent—both common best practices as well. To make sure that users had a consistent gallery experience, the application is limited to laptop and desktop computers as opposed to tablets, phones, and other mobile devices.

Other accessibility choices considered broad participant access to hardware. One well-known caveat of online research with remote samples is that there is very little control over what types of devices the participants use. While this isn't usually a problem for survey-focused data collection, this issue becomes much more apparent when using more technologically sophisticated study tools. Many widely-marketed virtual gallery tools, for example, have operating requirements that are too high to use on older or lower-tier machines. To combat this, OGAR was created using tools with low operating demand and the gallery environment forgoes more realistic and complex visual effects in lieu of simpler, computationally-light, and reliable graphics that are compatible with a wide range of machines and browser settings.

Taking steps to prioritize participant accessibility in OGAR aids its open science aims by allowing for more diversity in OGAR research samples. Considering the diverse needs and backgrounds of potential users allows researchers to gather data from more inclusive participant samples and accumulate richer data sets. Ensuring participant usability also reduces participant barriers, which leads to higher data quality and greater potential engagement with the tool.

Finally, prioritizing accessibility also helps open-source projects scale up to include larger numbers of community members and bigger use instances (in this case, studies).

However, accessibility isn't without its challenges. Despite sweeping efforts to ensure that OGAR runs on as many machines as possible, it is impossible to reliably test the tool against the nearly infinite and rapidly-changing combinations of machine hardware, browser configurations, and additional extensions that participants use on their personal computers. It is also difficult to be sure about what design choices are the best for users without extensive usability testing and evaluation.

A Proof-of-Concept Study

The extensive development work that went into creating OGAR culminated in the first paper discussed in the present dissertation. Published in *Behavior Research Methods*, Rodriguez-Boerwinkle and colleagues (2023b) introduced OGAR as an open-source virtual gallery tool directed at meeting the needs of arts researchers. After providing an in-depth description of the tool, the paper presents a proof-of-concept study designed to evaluate the participant usability and initial research potential of the tool.

The investigation begins by using a sample of 44 online adults to test several assumptions about virtual gallery experiences, including hypotheses that participants would travel further and visit longer in larger spaces and actively use that time to engage with artworks. Although they seem readily apparent, establishing empirical support for these assumptions is the first step in being able to systematically describe virtual gallery experiences and provided a solid foundation for subsequent OGAR studies.

After examined movement patterns revealed patterns of anticipated and reasonable use in the gallery, the research team looked at participant usability in OGAR. Our evaluation of participant usability used the System Usability Scale and self-reports of nausea, administered after gallery visits, to assess the accessibility of our design choices for the gallery client. The self-reports indicated that participants found the gallery highly usable and experienced rare occurrences of nausea.

Overall, OGAR's inaugural study suggested that the course of the tool's development was on a good track and it could make a promising tool for researchers interested in studying art experiences. As the OGAR project's initial development and release came to a close, however, many challenges still needed to be addressed. Additional features would be needed to make the tool more widely adoptable by arts researchers, and the first study using the tool was limited in terms of its sample size, gallery complexity, and measurement scope.

Stage 2: Expanding the OGAR Toolset and Research Program

After initial development efforts on OGAR were complete, the project underwent a phase of growth in multiple directions. First, there were substantial developments in the availability of gallery design tooling, server tooling, interactive gallery features, and packaged code for developing high-quality OGAR figures. Then, there was a realized need to expand testing to include larger samples and data for some ideas common in the psychology of arts literature. Finally, there grew to be an understanding of how OGAR could be used to address the collection of data that was difficult to do in person.

OGAR Developments

After gaining valuable feedback on the tool from participants, reviewers, and early readers of the first OGAR paper, it became clear that in order for OGAR to go from a promising to an effective research tool, more development work was needed. Much of this development work was completed in collaboration with the Humanities and Human Flourishing (HHF) group at the University of Pennsylvania, who were in need of a reliable tool to carry out their Covid-thwarted grant initiatives with the Philadelphia Museum of Art. Under the direction of HHF leadership, a graphical user interface, called *OGAREdit* (HHF Group, 2022a), was created to allow gallery designers to create floorplans, select gallery attributes, and import and curate visual stimuli to hang in their custom galleries. This additional software greatly lowered the bar for researchers interested in using OGAR by eliminating the need to interact with code-based gallery definition files in favor of a visual point-and-click approach.

Another contribution that was developed as part of the HHF collaboration was the development of *OGARCloud* (HHF Group, 2022b). OGARCloud is an Amazon Web Services system designed to unify the performance of five tasks—uploading and previewing OGAREdit galleries, integrating galleries with Qualtrics, serving static resources to participant web-browsers, collecting participant behavioral data, and exporting data for analysis—into one study deployment platform. This tool greatly diminished the need for server management and web-development experience, further increasing the tool's accessibility to the average researcher.

A final contribution that was spearheaded by the HHF group was the addition of several interactive gallery features. Namely, click-to-enlarge viewpoints, text association, and audio association were all added as gallery options for designers to enable or disable as they choose. Interactive gallery features are one important way that virtual art galleries differ from in-person ones. In addition to marking how experiences in these settings can be unique, however, they can also be used to test common ideas in the existing psychology of arts and visitorship literatures.

Parallel to the contributions of the HHF group, I developed an R-package, named *OGARPlots*, that created a series of layerable convenience functions for developing high-quality, complex plots of OGAR data. Given the standardization of OGAR output, some types of figures, such as outlines of the gallery floorplan, maps of artwork locations, and heatmaps of participant movement were common descriptive figures likely of interest to most researchers conducting OGAR studies. The purpose of the function set, therefore, was to decrease redundancy in creating basic figures from scratch every time someone was working with OGAR data.

Altogether, these updates represented the first substantive community engagement with the project. They also increased the accessibility of the tool for researchers and opened the door for a broader range of OGAR research to be conducted.

Exploring Established Ideas

After its initial validation, one of the biggest weaknesses with research on virtual galleries was simply that there was very little data available in this area. In addition to needing more participants to take part in these studies, the research program needed to identify the right variables to focus its efforts on. A good place to start expanding OGAR's program of research is with ideas that are commonly studied in the psychology of arts literature, such as artwork viewing time and viewing distance. Viewing time has already been established as a major variable in museum-based studies. It shows considerable individual differences (Smith, 2014), is greatly affected by social (Tröndle et al., 2012) and contextual factors (Reitstätter et al., 2020; Smith et al., 2006, 2017; Specht, 2010), and has been implicated as a predictor of visit satisfaction and museum fatigue (Specht, 2010). Likewise, the distance that someone chooses to stand from an artwork during viewing has received fair attention from arts researchers, albeit not as much as viewing time. Viewing distance varies as a result of artwork area (Carbon, 2017; Clarke et al., 1984) and other image properties (Estrada-Gonzalez et al., 2020) and may reveal considerable information about traffic flow through gallery spaces.

Starting with low-hanging fruit that have already been examined in other areas of arts research is useful for building a program of research on virtual art galleries, because it provides a contextual basis in which to understand this area of work. Seeking out work from parallel contexts, like museum studies, and reflecting some of that work in a novel context like OGAR helps establish the descriptive nature of virtual galleries and the experiences that occur within them by pointing to variables that likely to be of interest and providing a point of comparison between each class of experiences. Building on prior work is a fundamental piece of the scientific process. Here, starting with examining viewing time and distance in the virtual gallery helps demonstrate how this line of research fits into the broader academic conversation about art engagement. Once this context has been established, looking to common findings in the rest of the arts literature and comparing them with findings in virtual galleries will undergird new developments in theory, expanding our knowledge of those experiences. Finally, drawing from common variables in the rest of the arts literature serves to pull in traditional arts researchers and expand the community of scholars interested in virtual gallery research.

Testing New Ideas

Alongside examining more traditional variables, testing new ideas is also important for growing a program of virtual gallery research. While this is often the goal of science, it should not be seen as the end of the path. Instead, testing new ideas should be balanced with vetting existing literature and undertaken concurrently in many cases. In the present line of research, one of the first places this became evident was in the incorporation of individual difference variables into studies of virtual gallery experiences. This was a natural area to expand research efforts, given the well-established foundations offered by the psychological literature and methodological resources for studying personality. Further, research developments in this area would address current challenges faced in adoption by researchers conducting their work in museums. To elaborate, no additional measurement or software development were required to study the personalities of OGAR visitors, so implementation was a practical choice while more researcher time was being dedicated to solving other methodological issues with the toolset. At the same time, we realized that the strengths of virtual gallery studies could help provide a platform for testing ideas that are difficult to do in person. In the case of personality metrics, many of the survey tools used by personality researchers are long and impractical to administer in field environments such as museums.

Leveraging the strengths of new systems like virtual galleries can help researchers expand their fields and fill in gaps in the literature by circumventing common methodological problems. Taking these strides sooner rather than later—perhaps even during the process of establishing initial validity or exploring established ideas—leads to faster research progress and builds credibility in the new approach.

A Study of Personality and Art Encounters in Virtual Galleries

The expansions in the OGAR project's toolset and growth in the conceptual scope of this program of research on virtual gallery experiences prepared me to conduct the second research work highlighted in this dissertation, which was ultimately published in *Empirical Studies of the Arts* (Rodriguez-Boerwinkle & Silvia, 2023c). This work had several aims, including those that address sample size, a common data collection challenge seen previously in the literature, and the hierarchical structure of our art gallery visit data.

The first aim of this work was to improve upon some of the shortcomings identified in our pilot study of OGAR. One point of improvement was in the sample collected for our second study. The first paper that used the virtual gallery tool retained a rather small final sample, only

44 participants, which limited the integrity of our findings and would not be large enough to test hypotheses that amounted to more than easy-to-make assumptions about navigation use. The pilot study's small sample size came down to two factors: hedging our bets about a previously untested tool and failing to adequately consider for a high participant exclusion rate (27% that was compounded by inattentive responding, study incompletion, and technology issues), relative to survey-based online studies. Despite these initial challenges, the general success of our first study gave us the confidence to try the OGAR toolset with a larger sample and gave us the data we needed to greatly improve on technological factors leading to participant drop out ahead of this study.

The second aim of this work was to tackle the problem of assessing individual differences in visitors to gallery spaces and learn about those aspects of the visitor in a digital environment. In addition to being difficult to study in fast-paced museum settings, there was good reason to believe that personality and art-related individual differences would play a role in visit behavior. Although all the Big Five traits required examination since they had never been studied in this context, there was ample evidence in the arts literature on Openness to Experience to suspect that it would be related to more-engaged behaviors in OGAR. Openness to experience—how open-minded, curious, and willing to engage in new ideas or experiences a person is—had been previously linked to profound aesthetic experiences (Silvia et al., 2015), greater general preference for the arts and more frequent visits to art galleries (Chamorro-Premuzic et al., 2009), and, since the publication of this article, visual exploration in art gallery settings (Palumbo et al., 2023). Similarly, art knowledge—a person's understanding and familiarity with artists and art concepts—and aesthetic responsiveness—how strongly a person experiences and reacts to aesthetic stimuli such as art—were also hypothesized to impact indicators of visit engagement.

Previous studies have linked art knowledge to art appreciation and engagement in art-related activities (Atari et al., 2020; Belke et al., 2006). Aesthetic responsiveness, meanwhile, is a newer construct (Schlotz et al., 2021) that has been found to predict wellbeing benefits from online art viewing (Trupp et al., 2023). Beyond these general expectations, many of the findings in this study were exploratory, but greatly informative to our understanding of virtual gallery visits.

The last aim of this study was to study arts engagement in a way that recognized potential differences in behavior on the level of the participant and on the level of the artwork. In other words, it was important to capture how engagement behaviors with each artwork in the gallery could vary within the same visitor but show global patterns that were also distinct from other visitors. Therefore, in addition to looking at how individual differences in visitors impacted their between-person behavior, we also examined how artwork characteristics such as image size would predict within-person viewing behavior for a given artwork.

Overall, OGAR's second study expanded the validity of the tool with a larger sample, a more complex design, and more data. The results contributed to the arts literature on key, well-established variables and introduced a few new ones. With the conclusion of this phase in OGAR's development and research expansion, the tool was ready to make greater strides that challenge and stretch the conceptual definitions of visit behavior in art galleries and similar environments.

Stage 3: Leveraging OGAR's Capabilities to Enrich the Field

The final stage in development of this program of research saw a shift from expanding and testing the OGAR toolset and general framework of virtual gallery studies to making the most of the tool's capabilities.

Reconceptualizing Gallery Behaviors

A common target of most field work, behavioral measurement is at the center of gallery and museum research in the psychology of arts and visitor studies. Gaze (often quantified as viewing time or location) and, to a lesser extent, viewing distance, have been the focus of psychology of arts researchers and are often seen as indicators of top-down and bottom-up visual processes that are occurring beneath the surface of art-viewing (Heidenreich & Turano, 2011; Locher, 2006; Massaro et al., 2012). Researchers in visitor studies, on the other hand, are more often concerned with applied issues of visitor engagement and traffic flow through spaces. To this end, they also consider overall visit time, stopping behaviors, and navigational patterns (Bitgood, 2006; Bitgood & Patterson, 1993; Bourdeau & Chebat, 2001).

Conceptualizations of gallery behaviors by both groups, however, have been constrained by the methodological challenges of data collection in field contexts. In the psychology of art literature, gallery or museum contexts are prized by some researchers over lab-based data collection because they offer more ecological validity and complexity. Unfortunately, measures like viewing time wash out the richness of gallery experiences and reduce them to a measure that could be more easily captured in a lab setting. In the visitor studies literature, meanwhile, behaviorally complex visitor observations, such as preferring right turns or engaging with exhibits, remain often-noted but rarely quantified in concrete terms.

Some efforts are underway by arts researchers to redefine how behavior is examined in complex art-viewing settings. For example, some researchers are branching the behaviors they examine to include auxiliary actions like returning to artworks to view them again (Carbon, 2017), taking pictures or selfies with artworks (Carbon, 2017), and reading accompanying text or labels (Bitgood & Patterson, 1993; Reitstätter et al., 2022; Smith et al., 2017). Others are reorganizing how we think about behavior in the museum. Linden and Wagemans (2021), for example, developed a classification scheme to organize navigation behaviors, chiefly gaze behaviors, in art gallery environments into a hierarchical structure that emphasizes how several smaller actions may make up larger, more meaningful interactions. Similarly, Kühnapfel and colleagues (2024) emphasized the importance of shared patterns of engagement in their navigational study of a single painting. Still, a greater emphasis on how complex combinations of behavior—beyond simply gazing at a painting—are used to optimize our visual interactions and ultimately our emotional judgements and meaning-making of art objects is essential for developing our understanding of aesthetic engagement in the psychology of art.

From Conceptual Definitions to Quantifiable Measures

Virtual galleries have a lot of potential to contribute to the arts literature on this issue because of their highly defined nature. Since every parameter of the digital space must be defined by the gallery designer, these measurements are easily accessible during data analysis and can be paired with timestamped navigational measurements from participants to create a powerful picture of a person's gallery visit. In thinking about how OGAR's data could be combined, I identified ways that several meaningful variables could be robustly quantified.

Measuring Art Viewing

The first two metrics I identified were the number of artworks viewed and the viewing time ratio. Both measures represent the relative exposure to target objects that a person has during their gallery visit. The number of artworks viewed is a discrete number that can then be compared to the total number of available stimuli in the environment. If two different people spend a similar amount of time in the gallery, examining the number of artworks a person freely chooses to look at may reveal differences about their engagement preferences. For example, given the same time, does a person prefer to spend more time with fewer artworks or less time with many artworks? Calculating an art viewing ratio—the amount of time someone spends looking at art versus the total time they spend in the gallery—can give researchers a clue about how focused on the art that someone is during their visit. Generally, gallery visitors with a low art viewing ratio may be disengaged or spending their time focused on other stimuli such as phones, labels, or other people, during their visit. In a virtual gallery, however, this may indicate that a participant is having difficulty using the gallery, examining the architectural features of the gallery, or focused on off-screen distractions. In both cases, treating art viewing time as a ratio results in a measure of engagement that is not conflated with the total time that someone spends in the gallery.

Measuring Movement

The next set of measures I wanted to quantify were related to a person's overall movement through the gallery space. The amount of time spent stopped is a common variable used in visitor studies and is often associated with learning and overall exhibit success (Bailey et al., 1998; Bitgood, 2006; Sarasso et al., 2020). In OGAR, this is practically implemented as a timer that accumulates whenever a person's movement speed is 0 m/s. Being stopped in an exhibit may be indicative of distraction, but it also leaves room for sustained engagement with a particular artwork or external attention to people, phones, and other materials.

Directionality is another important descriptor of participant movement that could benefit from clearer quantification. Frequent observations by visitor studies researchers and applied museum personnel suggest that gallery visitors tend to prefer to rightward movement (see, for example, Bitgood, 2006; Garbutt et al. 2020; Whyte, 1988). Some sources even hypothesize that this pattern is related to right-handedness, local driving patterns, or influenced by the architecture of museum spaces (Robinson, 1933; Scharine & McBeath, 2002). However, this phenomenon has yet to be systematically recorded or tested using empirical methods. The virtual gallery offers a promising environment in which to do this, but quantification isn't without its challenges. Specifically, what should a measurement of directionality look like? Should a researcher tally up the number of times someone turns to the right or left more than 45 degrees? Should a measurement system for directionality base itself on cardinal directions or a polar coordinate system? While at first glance these seem like good options, two details need to be taken into account. First, measurements of directionality should consider movement in a new direction as opposed to simply turning in place. Second, the reference point for "moving left" versus "moving right" changes according to the orientation of the participant. A person facing north, for example, would turn eastward when moving right and westward when moving left whereas a person facing south would turn in the opposite cardinal directions. In a gallery setting, this complication arises when participants view artworks on the interior walls as opposed to exterior walls.

To account for these intricacies and make sure that quantified changes in direction were meaningful to the task of navigating a gallery full of art objects, I chose to build a measure of directionality based on the static locations of artwork hung in the gallery. Artwork placements for continuous walls (i.e., one list for the exterior wall and one list for each interior wall) were recorded as ordered lists. Then, each time that a gallery visitor proceeded past an artwork while being closest to it, the previous artwork passed was referenced to determine if the current artwork was to the left or to the right of it. If the newest artwork was to the right of the previous artwork, a rightward movement tally was recorded, and vice versa. At the end of the visit, the right and left tallies were summed to calculate percentages out of the total that a person moved in either direction, and the rightward percentage was subtracted from the leftward percentage to obtain a directional bias measure. As a result, the final measure indicated overall leftward bias as negative values, 0 as no bias, and positive values as rightward bias.

A third overall movement variable that I wanted to explore for use in the literature on gallery experiences was sinuosity. Typically used to study animal navigation trajectories in behavioral ecology, measures of sinuosity can be used to examine the navigational paths of participants walking through gallery settings. This measure can provide some idea of how "wandering" the navigational path of a person is, even if they stay within the vicinity of a single painting. Recording small-scale changes in movement have the potential to tell researchers a lot about how art viewers adjust their vantage points to optimize their viewing. When used on a larger scale, such as across the entire visit, sinuosity measurements might suggest how explorative a person's behavior in the gallery is. Due to their popularity with ecologists, there are lots of handy tools available for calculating sinuosity measurements, given X and Y coordinate navigation data. These tools can often be leveraged during the data preparation phase of the typical virtual gallery study.

Measuring Intensive Art Engagement

Perhaps the most important class of measurements I wanted to consider and develop further are those related to extended engagement with art. Deeply engaging with an artwork—more than simply gazing at it as you walk past—can be described as a combination of multiple simple navigation and perception behaviors such as approaching, stopping, and gazing (Linden & Wagemans, 2021). Deep engagements, like prescribed slow-looking exercises, have been shown to promote psychological well-being (Cotter et al., 2023a) and learning (Tishman, 2017). Intensive engagement, however, has not been widely studied in free-choice observational studies of gallery behavior before. This is likely because there are too many simple behavioral actions going on simultaneously to easily capture in field environments; if a field researcher would like to do more than code the interaction by hand, both gaze and location data, at minimum, would be required to robustly measure deep engagement with artwork.

In order to study this level of engagement, therefore, it was first necessary to develop a set of behavioral parameters for what constitutes an art visit. To begin, I reasoned that a person must be closer to a target artwork than any other artwork and currently viewing it. The rationale for this is simple: if you aren't currently looking at a work of art, then you are probably not interacting with it, and if you are looking at it, but you are across a room or closer to another artwork, then you are likely engaged in other tasks such as deciding whether to engage with it or comparing one artwork to another. To these constraints, I added in the condition that a person must have looked at a different artwork before the currently viewed artwork. This detail ensures that briefly looking at a label or quickly shifting attention to a temporary distraction do not end the art visit, but shifting one's gaze from one painting to another does. Finally, to qualify as an intensive art engagement, I required that participants be stopped for at least one second. This criterion recognized the attentional importance of stopping behavior, without placing overly strenuous expectations on what should be considered an art "visit."

Continuing this logic, I also defined what I call "artwork revisits," whereby a person goes through all the behavioral steps of deeply engaging with an artwork and then later decides to engage with the artwork again. Although the literature on returning to artworks for additional viewing is sparse, some work documenting this phenomenon notes that second or third rounds of observation can be quantitatively different from initial engagements with an artwork, with viewing times increasing substantially during return viewings (Carbon, 2017). This may suggest that art gallery visitors sometimes “screen” artworks during initial visits to determine personally significant objects that they would like to return to for further inspection. Given the economy of movement at play in museum settings, whereby people will weigh the perceived experience outcome of continuing their visit versus its perceived costs (Bitgood, 2006), voluntary artwork revisits represent an interesting option for future study.

While I think this list of conditions is useful for my own work and can easily be expanded to find use in traditional field work as well, other researchers may want to consider the theoretical and methodological implications of the parameters they set or consider adding and excluding other behaviors from this set altogether. In total, I think types of measures discussed here are worth considering for broader use in arts research, but the specifics of their implementation may vary from study to study.

A Multidimensional Analysis of Visitor Behavior

Recently submitted to the *International Journal of Human-Computer Interactions*, the third paper featured in the present dissertation represents the culmination of OGAR development and conceptual work on art gallery behaviors that make up this line of research on virtual art galleries (Rodriguez-Boerwinkle & Silvia, 2023d). This manuscript demonstrates the depths of OGAR’s research capabilities in a three-phase analysis and classification of visitor behavior. First, an extensive view of the question, “what does a virtual gallery visit look like?” was undertaken using the newly described behavioral metrics discussed above. Then those measures, along with gallery visit time and distance traveled, were used to estimate possible visitor engagement groups based on a latent class analysis. After classes were identified, their levels of several individual difference variables were examined.

Overall, each phase of this research overcame distinct gaps in the psychology of arts literature and potential research applications. The first phase expanded the psychology of arts literature on visit behaviors by addressing current oversimplifications in the collection of engagement behavior with the introduction of new measures and paradigms. The second phase grouped virtual gallery visitors based on quantifiable behaviors, which can help others recognize meaningful patterns in engagement through visitor behavior. The final phase investigated whether behavioral classes differed in terms of common individual difference measures, thus allowing applied personnel to imagine how museum and exhibit design could consider the individual visitor to strengthen aesthetic experiences and educational outcomes.

General Aims

Over the course of this work, I develop a framework for effectively integrating research using virtual gallery tools into the psychology of art and aesthetics. Broadly, this framework suggests that virtual galleries have found three potential use cases in the psychology of art (Rodriguez-Boerwinkle & Silvia, 2023a). First, they are useful in situations where traditional field research is difficult or results in imprecise behavioral measurements. In this way, virtual gallery tools have the potential to support and enrich ongoing lab and museum-based research in the psychology of arts and aesthetics. Second, they can complement in-person research as a planning and pilot testing tool used before or alongside large-scale field work. Although important, this potential use is not a focus of this dissertation for reasons of scope. Third, trends in digital art engagement indicate that virtual galleries have gained their own relevancy as an important context for art experiences. This suggests the emergence of virtual galleries as a substantive intellectual context for study, similar to other institutional settings, with its own unique opportunities for psychological inquiry. In other words, this research demonstrates that virtual galleries are another place where art “is”—not merely another tool for approximating psychological experiences.

Accordingly, the present dissertation synthesizes three papers that, with my commentary, demonstrate the intellectual development of the OGAR project and corresponding development of research on experiences in virtual art galleries. The selected papers represent a cohesive program of research that aims to answer the question, “where is art?,” advances open-source and open-science aims, and tackles important methodological issues in the psychology of art and visitor studies. Each section of this cumulative work represents an ordinal step process and culminated in a unique paper that demonstrated the development and expansion of this project while simultaneously tackling some of the psychology of art’s biggest questions about museum and gallery visits and visitors.

After presenting each paper, this dissertation will end with an integrated discussion to contextualize the current state of this work within the field, including where the OGAR project is now, recent research developments by other researchers using virtual galleries, and emerging directions where I think virtual galleries might prove useful. Namely, I’ll highlight some research projects and development work currently underway with OGAR, including efforts to conduct a robust comparative analysis between art engagement in OGAR and art engagement in a parallel in-person gallery space. I will also discuss the tool’s adoption by other researchers and how this work has impacted research using other virtual galleries and digital tools. After talking about these advancements, I will conclude with some pressing issues that remain with the research program. These limitations include some outstanding conceptual challenges related to conducting psychological research using virtual galleries, highlighting the need to carefully consider how they can best contribute to future arts and aesthetics research.

CHAPTER II: THE OPEN GALLERY FOR ARTS RESEARCH (OGAR): AN OPEN-SOURCE TOOL FOR STUDYING THE PSYCHOLOGY OF VIRTUAL ART MUSEUM VISITS

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Rodriguez-Boerwinkle, R. M., Boerwinkle, M. J., & Silvia, P. J. (2023b). The Open Gallery for Arts Research (OGAR): An open-source tool for studying the psychology of virtual art museum visits. *Behavior Research Methods*, *55*(2), 824–842. https://doi.org/10.3758/s13428-022-01857-w

What were once private collections guarded by the societal elite, symbols of wealth and status, and a means of distinguishing between the "cultured" few and the "uncultured" many, art museums are now cultural institutions that aim to serve the masses (Bennett, 2013). With stated mission statements like the Metropolitan Museum of Art's— "to collect, preserve, study, exhibit, and stimulate appreciation for and advance knowledge of works of art"—museums now emphasize their roles as disseminators of knowledge and culture (Metropolitan Museum of Art mission statement, 2000). As part of this mission, the interdisciplinary study of the psychology of museum experiences—grounded in the psychology of the arts, visitor studies, and art education—seeks to understand how people experience, understand, and learn from their time spent in art museums (Tinio et al., 2015).

In the present research, we aim to expand the tools available to researchers in this growing scholarly field by developing the open gallery for arts research (OGAR). OGAR is a free, open-source tool for studying visitor behavior within an online gallery environment. It is highly extensible, allowing researchers to modify the environment to test different hypotheses, and it affords assessing a wide range of outcome variables. After reviewing relevant literature and describing the tool and its development, we present a proof-of-concept study that evaluates OGAR's usability and performance and illustrates some ways that it can be used to study the psychology of virtual visits.

Psychological Research in Art Museums

To keep up with patrons, museums need to house objects that are important not just to individuals but to groups of people. Further, they must be able to present those objects in a way that is meaningful to those groups. This has led to recent efforts to recast museums as more "user friendly" and to engage visitors in a more participatory way (Choi, 2013). Increasing emphasis is being placed on identifying who the audience is, how they interact with individual objects or entire galleries, what information they take home with them, and what meaning they assign to their experiences (Brieber et al., 2015; Leder et al., 2012; Smith, 2014).

Traditionally, the psychology of art has worked to answer some of these questions through studies of individual artworks in lab settings, which offer superior controllability. However, the field recognizes that lab settings do not offer the proper context under which artworks are normally viewed. For example, participants who freely visited an exhibition in a museum viewed the artworks for longer and gave them higher subjective liking and interest ratings than participants who viewed the same exhibit in the lab (Brieber et al., 2014), and participants had greater affective appreciation for, and memory of artworks viewed in a museum context (Brieber et al., 2015). There are increasing efforts to study the psychology of art and aesthetics in real-world, ecologically-valid contexts such as museums, galleries, sculpture gardens, and street art sites (Mitschke et al., 2017; Pelowski et al., 2017; Specker et al., 2017). By and large, art museum research uses both recruited and natural visitors for participation.

Participants are often given questions or task instructions before beginning their visit and asked to complete some questions or tasks during or after the visit. Researchers often use mobile eye tracking units (Garbutt et al., 2020; Santini et al., 2018), GPS devices (Estrada-Gonzalez et al., 2020), tablets (Cotter et al., 2022a; Rodriguez et al., 2021) smart phones (Specker et al., 2020), or simply pens, paper, clipboards and stopwatches (Smith & Smith, 2001, 2006) to capture data during each participant's visit. Data collection may be primarily interested in background measures and post-visit responses, or focused on eye gaze, viewing time, social behaviors, and movement path (Pelowski et al., 2014, 2017).

There are many strengths to this type of field research. Studying art viewing in museums provides richer context and therefore greater ecological validity than lab studies. In addition, the museum context lends itself to stronger aesthetic experiences with greater appreciation and engagement with the artworks (Brieber et al., 2014). Researchers can examine relationships between individual artworks or the entire visit as a whole unit instead of individual works (Smith, 2014). One can also investigate the effects of spatial features like room size or wall color and intentional curatorial choices regarding theme, style, artwork placement, lighting, and accompanying text (Pelowski et al., 2017; Specker et al., 2020). Finally, social interactions with other visitors present in the gallery can necessarily only be studied in a social space (Pelowski et al., 2014).

Unfortunately, field research in museums also has its challenges. It is often as hard to take research into a museum as it is to bring in a bottle of water. Museum staff can be wary of outsiders, so trusting relationships and effective partnerships take time to build. Once researchers are in the building, willing participants can be difficult to attract. All told, most researchers who conduct field research in museums would agree that it is intensive in time, labor, and research personnel.

Another challenge involves manipulating field environments. Few curators will allow researchers to vary aspects of their exhibits (see Reitstätter et al., 2020, for a good example). Other changes, like room size and wall color are simply impossible to alter for the sake of an experiment. And as recent experience shows, data collection may be limited or impossible in times of public health crises and other events that limit access to field sites.

Current Virtual Art Gallery Tools

Field studies in museums have many strengths yet pose significant challenges for researchers. One way to balance the trade-off of realism and control is to use virtual gallery tools and simulations. While there's nothing quite like being in a real museum, virtual gallery environments offer an opportunity for a middle ground between the realism of a museum environment and the controlled-but-sterile environment of a research lab.

In recent years, many museums, galleries, and presentation venues have turned to virtual environments for a wide range of uses in addition to their traditional in-person spaces. For example, schools and educational environments may use virtual spaces to provide in-depth exploration and experience-based educational activities. Museums, galleries, and cultural sites may use them to reach people who are not able to visit otherwise or to showcase elements of their collection that are not often on physical display.

The emergence of virtual spaces as innovative and practical alternatives to traditional spaces has been further fueled by several factors. The explosion in virtual reality and growing interest in virtual media have both been big contributors to growing desire for virtual environment tools in business, starting as far back as the 1990s (Leston, 1996; Patel & Cardinali, 1994). The outbreak of the COVID-19 pandemic and resulting rise in social distancing measures aimed at closing access to public spaces has been another (Agostino et al., 2020). Although there have been a wide range of implementations for virtual spaces, here we will review those used primarily for displaying and sharing artwork.

Perhaps the most well-known tool has been the Google Arts and Culture Project. First launched in 2011, Google Arts and Culture has since partnered with over 2000 major museums and cultural institutions around the world to create online simulations of entire museum spaces for free to both the partnering institution and online visitor (Google Arts and Culture Project, 2011; Proctor, 2011). Their process works by using a trolley system to take thousands of pictures of a museum's interior and digitally stitching them together to create a 3D environment. Then, using software developed for Google Street View, users can navigate the space using a process known as animated interpolation, whereby a person clicks on a point in the distance and undergoes a smooth ("animated") viewpoint transition ("interpolation") from one point in space to the other (Moghadam et al., 2020). This method is somewhat akin to teleportation, but the position change is not instantaneous; instead, avatars are slid along a line from point A to point B.

Another class of popular tools, two of the most popular of which are Artsteps and CAPTURE3D, allow a creator to personalize digitally rendered 3D spaces and share those either privately or publicly. These tools are useful because they allow the user to customize their own virtual spaces and upload their own images using intuitive graphic user interfaces and canned design features. They also allow additional features like over-screen informational pop-ups when artwork is hovered over or clicked on. Movement for these spaces also takes advantage of animated interpolation.

Finally, more intensive tools have been suggested, such as Ikei et al.'s (2013) virtual experience system for digital museums, which uses "a three-dimensional visual display, a spatial sound, a haptic/tactile display for a hand and foot, a wind and scent display, and a vestibular display" (p. 204) to create a multisensory theater aimed at use in interactive exhibits. This type of tool, however, has not achieved wide use.

Using virtual gallery simulations for basic and applied arts research has the potential to overcome many of the challenges associated with traditional museum research. With a little help from online survey platforms, researchers can easily access large, diverse online samples. Virtual spaces are also easily manipulated: several available options allow gallery designers to manipulate floorplans, wall and ceiling colors and textures, and artwork size and placements. Finally, online data collection is safe during public health crises and accessible on most computers, bypassing difficulties in transportation and access.

Unfortunately, there are also limitations with existing tools that constrain their capabilities for research use. First, the process used by Google and digital tools like Artstep and CAPTURE3D are too expensive to be practical for research use. Second, none of the currently available tools are extensible, which prevents researchers from modifying applications to ask new questions. This severely limits their ability to collect and export research data for analysis of how the virtual visitors engage with the environment and artworks, such as how and where they move and what they view. Finally, systems using animated interpolation—although clearly preferred due to its ability to translate to mobile or touchscreen devices—are visually disjointed, which limits the ecological validity of virtual galleries when used as proxies for in-person experiences and tend to create motion sickness (Moghadam et al., 2020).

The Open Gallery for Arts Research (OGAR)

To provide a low-cost, versatile, and extensible tool for researchers interested in studying the unique characteristics of virtual art gallery spaces that are becoming increasingly common additions to traditional exhibits, or for those seeking greater ecological validity than lab studies but greater control than traditional museum environments, we created OGAR, the Open Gallery for Arts Research. OGAR is best understood via a *see-it-for-yourself* approach, so a sample walk-through video is available for viewing at Open Science Framework (https://osf.io/cwumb/). OGAR is composed of two parts: The OGAR Client, which presents the gallery to the user; and the OGAR Server, which receives and records activity information from instances of the Client. The OGAR Client runs individually on each participant's computer, while the Server runs on an internet-connected server. Our study integrated the OGAR Client in a page of a Qualtrics survey, but it can be used standalone, implemented in lab-based software, or integrated into most online survey providers.

User Interface

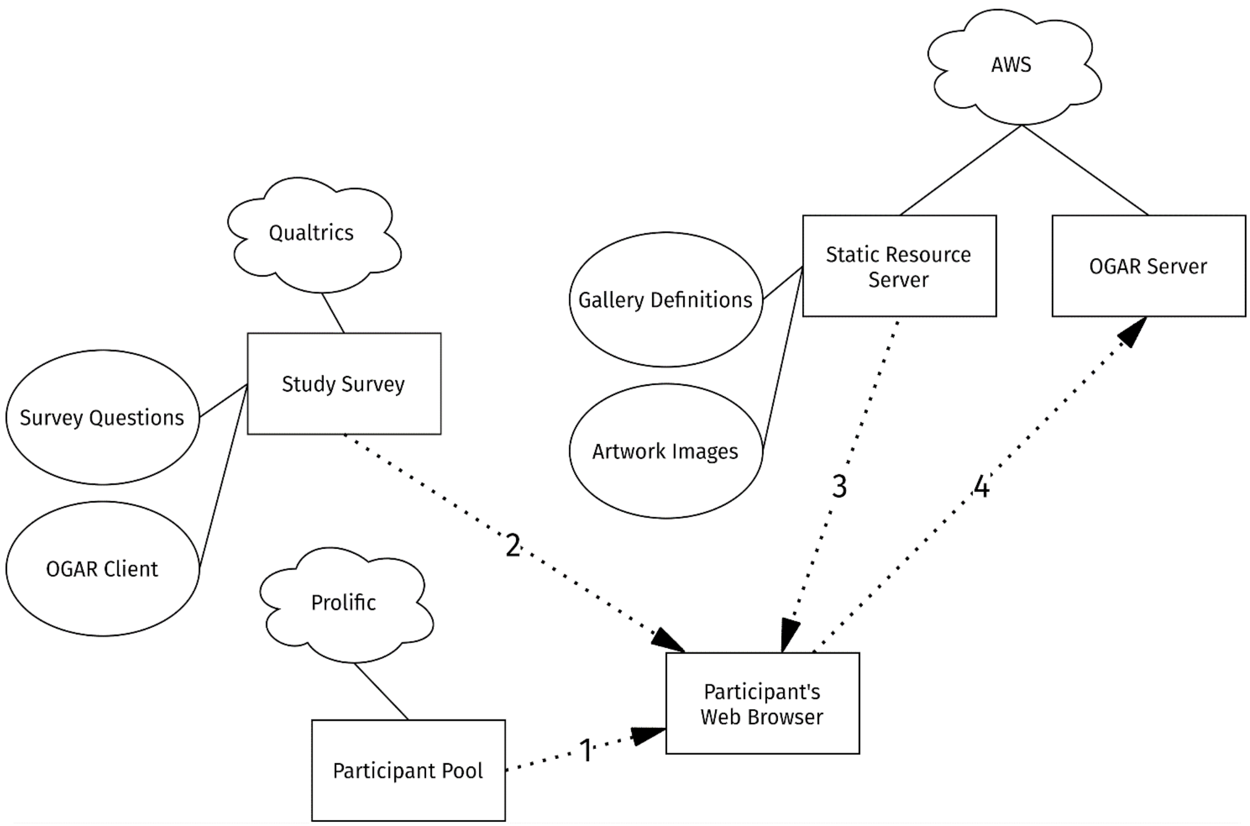
From a user perspective, the gallery is experienced as a simple 3D space with a first-person viewing perspective. For this application, we chose to use keyboard-controlled smooth movement with mouse free-look. The user can change where they look by moving their mouse, and they can change their avatar's location by holding the arrow or W, A, S, and D keys on their keyboard. This choice was informed by informal control and interface best practices that have gained popularity in recent decades for applications and games using 3D first person perspectives (Laramee, 2002, as cited in Whitty et al., 2010). Users, via their avatars, move freely throughout the space within the walls of the researcher-designed gallery layout. Movement speed accelerates to a standard walking pace of 1.8 m/s, and artworks are sized to reflect the true size and proportions of those pieces in real life. Due to its wide usage in film and media and documented preference by the viewing public, aspect ratios are set at 16:9 (Nystrom & Fairchild, 1992). The gallery is set to visually refresh at the device's screen refresh rate (typically 60 fps), and resolution is device dependent and varies by participant.

The user can see floor, ceiling, and walls that are colored and flat. In addition, predetermined artworks are clearly visible hanging on the walls of the gallery. The gallery's features can be easily modified by the investigator with little limitation. For example, researchers can vary the floorplans, the artworks and their placements, the colors of the floor, ceiling, and walls, the gallery lighting, movement controls, and environment physics. As the user interacts with the gallery, their position and view are recorded.

System Architecture

To collect participant data, internet-connected infrastructure is required. Our study used two servers and Qualtrics. The OGAR Client was embedded into a Qualtrics survey using Qualtrics's *Add JavaScript* feature on an otherwise empty question. This embedded JavaScript includes only the Client program but does not include any gallery contents. First, the OGAR Client reads configuration in its environment to determine what it should present. In our study, it used Qualtrics Embedded Data to determine which gallery plan should be presented. Next, the OGAR Client fetches the gallery definition, art images, and other resources from a static file server. This server operates as a typical HTTPS server and can serve the gallery contents publicly over the Internet. While these resources are being retrieved, the client displays a loading screen to the user. As a final preparation step, the Client connects to the OGAR Server and prepares to send interaction data. When these steps are complete, the OGAR Client displays the gallery to the user. As the user interacts with the Client, it sends position and view information data to the OGAR Server. In addition, other events—such as gaining and losing browser focus and full screen status—are sent to the Server as they occur. A diagram of OGAR system development can be seen in Figure 2.1.

Figure 2.1. Diagram of OGAR System Deployment



Note. Participants start by being assigned the study through Prolific (1). Next, participants are directed to Qualtrics, where they connect to the survey (2). The survey contains the OGAR client. The OGAR client connects via the Participant's web browser to the static resource server hosted on AWS to retrieve its gallery definition and required art images (3). Finally, the OGAR client connects to the OGAR server to record the participant's actions (4). In this diagram, "clouds" are service providers, "boxes" are semi-tangible architectural elements, and "ellipses" are general resources owned by the boxes. Solid lines represent ownership, and dotted lines represent the action of data being transferred to and from the participant's web browser as they interact with the overall system.

Technologies Used

The OGAR Client is written in JavaScript and executed within participants' web browsers. It uses the standard WebGL version 1 interface (*Web Graphics* library; Khronos Group, 2011), which is a web standard for the development of web browser compatible 3D graphics interfaces, to render the gallery to the user in an HTML canvas element (Mozilla, 2021). During use, the Client program opens a WebSocket to the OGAR Server and sends updates to record the user's actions. The Client also interacts with the Qualtrics JavaScript API for interacting with Qualtrics Embedded Data and controlling survey flow.

The OGAR Server is a Python3 script that uses the Python *WebSockets* library (Augustin, 2021) to receive connections and data (in this case in-gallery user movements, view direction changes, and other application events) from the Client. The resulting data is recorded in a SQLite3 database (Hipp, 2021) where each client connection by a study participant has a random identifier, which allows reconciliation and linking with Qualtrics study results. For this study, we executed the OGAR Server on a Debian 10 server running on an EC2 T3.Micro cloud instance from the cloud provider Amazon Web Services (AWS).

Gallery Definition

The OGAR Client displays a gallery based on its *gallery definition*, which is created by the researcher according to their needs. These definitions are formatted as JSON Objects (ECMA-404, 2017). The definition format is minimal, but it is designed to be easily extensible as future studies require. In this study, two premade, static JSON files were used, but this JSON data could potentially have any source, such as existing architectural plans for real-life spaces, or could even be generated based on study data. For a gallery to be defined completely, several parameters must be outlined.

In terms of defining the room features of a virtual space in OGAR, the gallery designer must specify a “walls” list that determines the location of walls in the gallery. This list contains sub-lists that stand in for chains of walls where the end point of one wall is the start of the next wall. Each wall chain is an even-numbered length list where every two numbers determine the Cartesian coordinates of the next wall point. All wall chains have a minimum length of four numbers (two (X,Y) pairs) to define a single wall. For example, a value of “walls”: [[0,0, 1,0, 1,1], [5,5, -5,5]] defines two wall chains. The first wall chain consists of two walls—one from (0,0) to (1,0) and the second from (1,0) to (1,1). The second chain consists of a single wall from (5,5) to (-5,5). The whitespace between coordinate pairs is optional within the constraints of the JSON format. The gallery designer must also set “wallHeight,” a numerical value that determines the height of walls in meters. A value of 3.05 was used in this study. Finally, a “texture” string must be included to describe the source location of an image which defines the colors of the walls, floor, and ceiling. This image will be retrieved from the static resource server. For the current study, this image consists of three pixels, one for each of the three colors, but it could be extended to instead have three repeated textures.

To place artworks or other stimuli within the virtual environment, the creator must specify an “art” object that contains uniquely named definitions for each artwork in the gallery. Each art definition is an object that must include a “size” list containing the dimensions of the art and a “texture” string that describes the location of the source image on the static resource server. For example, the Mona Lisa may be defined as “LV_MonaLisa”:{“size”:[0.53, 0.77], “texture”:”img/monalisa.jpg”}. The gallery designer must also define an “artPlacement” array of objects. Each object in the array describes the specific placement of an artwork within the gallery with the following parameters: an “art” string that references a member of the top-level “art” object, a “dir” value that indicates the orientation of the art around the vertical axis in degrees, and a “loc” coordinate array that provides the X and Y position of the artwork in the gallery. In addition, a “height” value must be specified that determines the height of the center of the artwork from the ground.

Finally, to facilitate the first-person experience of the gallery, a “patron” object must be defined to set information related to the user’s avatar. This includes a “height” numerical value that determines the user’s eye height and a “start” coordinate pair list that sets the user’s initial location. For this study, we placed the user’s eye height at 1.65 m and specified their start location at [0,0] (the center of the room) within each gallery.

Data Format and Collection

WebSocket is capable of full-duplex communication, but in this application the communication is unidirectional, and no data is sent to the client from the server. Upon loading, the OGAR Client connects to the OGAR Server running at a preconfigured Internet address. Once a connection is established, the Client sends introductory data. After that, the Client reports the avatar’s position within the gallery every 200 ms and other events as they occur. To avoid inaccuracy stemming from variable network delays, or jitter, caused by congestion and other factors, every message is timestamped by the OGAR Client.

Data is recorded by the OGAR Server in a relational database, which has multiple tables connected by reference keys. The primary table, titled *participant*, contains all connections made to the Server by Clients. Each connection is assigned a unique identifier, and Clients may also pass their own self-reported identifiers. In this study, Clients passed an ID generated by

Qualtrics, and defined as Embedded Data, as a key for future relational joining with the Qualtrics survey results. This *participant* table also holds assorted other client information, such as connection and disconnection time.

Another table, *position*, records position data for each participant. Each entry in this table is a single position (and view direction), at a single time, for a single user's avatar within the gallery.

Two other tables, *event* and *error*, record events and errors, respectively. The specifics of what is reported may significantly vary in future implementations, but in this study, we recorded events related to mouse-capture in the Client and the full-screen status of the Client. In addition, we created error reports for certain technical problems we thought might arise, but none of those checks triggered during this study.

Data Processing

The OGAR Server's collected data goes through several clean-up steps to make it easily ingestible by statistical software. All these steps take place after data collection is finished.

In particular, OGAR reports unprocessed timestamps as either integer UNIX Epoch seconds alone (for errors and events) or in combination with integer milliseconds (for position data). These timestamps are converted into seconds as floating-point values with the time origin at the connection time for the associated Client. Periods when the participant was inactive (as determined by them exiting full screen and surrendering avatar control) were removed from these recomputed timestamps. This allows statistical software to operate purely on when the participant was active as a single contiguous chunk of time.

Another data processing task is view-determination. A custom utility program recreates the gallery for each position table entry (i.e., at each timestamp) and records what the participant in that position was viewing. This calculation determines the first intersection of a ray originating at the avatar's eye and traveling in the direction of the center of their view. The resulting intersections are labeled *wall*, a specific named artwork, or *nothing* depending on what the participant is viewing.

Criteria for Data Elimination

The OGAR client may not function correctly on every participant's personal computer. Projects using remote samples (e.g., online survey panels) can usually enforce some software or hardware restrictions as eligibility criteria, but many factors, such as software versions and background load, affect performance. Because of this, some participants will create data that should not be considered for analysis. As an example of selection criteria, for the current study participant data were excluded based on the following in-gallery behaviors, indications of abnormal loss of connection, and apparatus-specific signs of poor or malfunctioning browser performance:

- The participant never controlled their avatar with the keyboard. (The avatar's position never changed within the gallery.)
- The participant never moved their mouse. (Their view direction never changed.)
- The maximum distance traveled between avatar position updates was too low. (This is an indicator of poor performance, since position reporting occurs every 200 ms regardless of load, but movement happens uniformly, which may be impacted by excessive load.)
- Events related to mouse-focus and full screen were not reported in rational patterns (e.g., if a client enters full screen, they should exit full screen before the client exits the gallery and continues with the Qualtrics survey). These conditions were likely related to

uncommon browsers, behavior-altering browser extensions, or failed browser-mandated user-confirmation checks.

There is significant variability in the performance and functional characteristics of browsers on personal computers, so it is expected that at least a few participants would encounter poor or incorrect functioning, but these measures represent the minimum criteria needed for the gallery to provide a roughly equivalent experience between users.

Cost

In the spirit of accessibility to researchers with a wide range of backgrounds and resources, we designed for resources that are relatively accessible and affordable. As an example, the complete OGAR System set up for use during this study used one AWS T3.Micro instance with 8GiB EBS storage for static resource serving and one for the OGAR Server (~$8/month each). Network bandwidth to and from these two servers was included in the free-tier of AWS, thus incurring no additional cost. In addition, we purchased two domain names and paid $0.99/each/year for 1.111B Class .XYZ domains, but domain name access varies and is provided by some institutions. All told, the entire OGAR System was implemented for less than $20 per month of data collection for the current study. Setting up an AWS server to run with Qualtrics and recruiting paid Prolific participants for participation in our study proved to be a cost- and time-effective approach for our team, but OGAR can be set up to work in a variety of formats. For example, OGAR could be imbedded in a free online survey software instead of Qualtrics, or given developmental changes, in lab-based software so that data collection could be done with student or community samples without online tools, and AWS, of course, could be exchanged with a number of other server set-ups.

Evaluating OGAR

In the present research, we collected "proof of concept" data to assess the potential of OGAR as a tool for studying visitors within a virtual art gallery. A sample of adults was recruited from an online research participant panel (Prolific.co), and the participants were allowed to freely explore the virtual gallery and view the artworks within it. We focused on the OGAR's performance in two key areas: gallery usability and measurement validity. Gallery usability was evaluated using participant responses on the System Usability Scale (SUS; Brooke, 1996), self-reported nausea, and open-ended reports on user experience immediately after exiting OGAR. The usability data were collected to inform the participants' experience of navigating and interacting with the gallery and to discern how "user friendly" they found it.

Measurement validity was evaluated by manipulating aspects of the gallery and measuring behavior within it. We focused on some fundamental hypotheses that, while obvious and perhaps banal, would nevertheless have to be true for researchers to have any confidence in the validity of OGAR as a research tool. For validity data, we manipulated the size of the gallery—one room or two rooms—as a between-person variable. The two-room gallery had double the number of artworks and double the area, so the manipulation afforded testing some critical assumptions of successful use: (1) as the gallery space increases, participants will spend more time within it; and (2) as the gallery space increases, participants will travel a greater distance when navigating it.

Finally, for further evidence for the measurement validity of OGAR, we evaluated whether participants interacted with the artworks—that is, whether their time and movement within the virtual gallery was guided by the artworks as opposed to random or listless movement. Participants' positions in the gallery, movement trajectories, and viewing points were analyzed to discern how they traveled through the gallery, where they stopped, and what they viewed. Taken together, the usability data and the participants' behavior within the gallery should shed light on the value of OGAR as a tool for research on virtual art spaces.

Method

Participants

The present study was approved by the University of North Carolina at Greensboro Institutional Review Board (Study #21-0311), and all participants provided informed consent. A total of 61 adult participants were recruited from the Prolific.co survey panel and paid USD $4.00 for their participation. To be eligible, participants were required to be within the ages of 18 to 70, to be native speakers of English, and to have a minimum Prolific.co study approval rate of 90%. The study was advertised as "desktops only" within the Prolific system (i.e., tablets and smartphones were not permitted, but laptops were). After screening for inattentive responding, drop-out, and technology issues (described in detail later), the final sample consisted of 44 participants—19 women, 25 men—who ranged in age from 19 to 60 (*M* age = 31.73).

Procedure

Prolific participants were redirected to a Qualtrics survey for the duration of this experiment. People were prompted to provide basic demographic information—their age, country of residence, and gender—before proceeding to the gallery. When the participant arrived at the specified "question," a preview window of the gallery was shown that expanded into full screen when the user clicked on the window. At this point, full controls were enabled, and the participant could navigate the gallery using their keyboard to move cardinally to the view direction. The user could change their view direction by moving their mouse. Participants could peruse the space for as long as they wished. After participants completed their visit, they were able to release their controls, exit full screen mode, and return to the Qualtrics survey by pressing the *Escape* key. The remaining part of the survey involved a series of follow-up questions about their experience.

Artworks

Sixteen artworks were selected for use in OGAR, based on prior approaches to artwork selection in similar studies (Belke et al., 2010; Leder et al., 2012). We procured high resolution images from the ARTSTOR digital library and public domain images from WikiArt. A full list of artworks is available in the Appendix. Where possible, artwork choices reflect those directly used in Belke et al. (2010). However, due to high quality requirements of our application and licensing constraints, some images were replaced with similar works from the same artist or other works. As a rough guideline, we aimed for artwork images between 20 and 50 dpi to ensure high enough image resolution without excess strain on client image download speeds. Artworks were categorized as either representational or nonrepresentational, with equal numbers of each mixed throughout the gallery. The artwork was placed to mimic realistic curation in physical gallery spaces, using aesthetic design principles outlined in Adrian George's *The Curator's Handbook* (George, 2015).

Gallery Manipulation

Gallery area was manipulated between-person. Participants were randomly assigned to be placed in either a one-room or a two-room version of OGAR. The two-room version appended the additional room directly adjacent to the first room, accessible by an open doorway. The one-room manipulation was enclosed by four walls. Rooms were identical dimensions (10 × 10 m), with the first room of both versions containing the same 8 artwork placements and the second room of the two-room version containing an additional 8 artworks. Total gallery area and number of artworks were doubled, so that artwork placement in the first room is consistent (with the exception of slightly wider placement between two artworks to accommodate the doorway in the two-room version) for both conditions, and comparisons concerning number of artworks and distances are facile.

Measures and Outcomes

Browser Data

Qualtrics was set to capture each participant's browser type, browser version, operating system, screen resolution and user agent. This information was used to investigate poor gallery performance in specific cases, so that the system can be improved in later study iterations.

Gallery Data

The gallery receiver server collects time-based position and gaze data for each participant every 200 ms. Location is recorded in X and Y coordinates with one unit corresponding to one meter of distance in the gallery. Gaze data consists of yaw and pitch and is defined in terms of radians.

User Feedback

Usability for OGAR was qualitatively assessed via user feedback from the SUS, as well as a few additional questions specific to the gallery, a directed-response item to flag inattentive responding (Maniaci & Rogge, 2014), and an open-ended prompt for additional comments (see Table 2.1). Since its initial publication, the SUS has been widely used in human-computer interactions research and product evaluation for computer systems (Lewis, 2018). The SUS assesses perceived usability through a 10-item questionnaire with response options scaled from 1 (*strongly disagree*) to 5 (*strongly agree*; Brooke, 1996), and it is designed to be implemented following task-based usability testing. Items are all first-person statements about personal user experience, like “I thought the system was easy to use” and “I found the system unnecessarily complex.” In the present study, the word “system” was replaced with the more specific descriptor “virtual gallery” in line with wording recommendations put forth by Lewis and Sauro (2009).

To create an overall score from the 10-item SUS, all participant responses are shifted so that the lowest possible score for each item is 0 and the highest possible score is 4. Then, even-numbered items are summed and odd items are each subtracted from the sum of the positive scores. The resulting total is multiplied by 2.5, which converts the range of possible values from 0 to 100. A score of 80 is commonly used as a threshold for good system usability (Lewis, 2018). Internal consistency measures for the SUS range from $\alpha = .83$ to $\alpha = .97$, with most studies placing it at about $\alpha = .90$ (Lewis, 2018).

Table 2.1. Usability Questions

System Usability Scale (SUS): 10 Items
1. I think that I would like to use this virtual gallery frequently.
2. I found the virtual gallery unnecessarily complex.
3. I thought the virtual gallery was easy to use.
4. I think that I would need the support of a technical person to be able to use this virtual gallery.
5. I found the various functions in this virtual gallery were well integrated.
6. I thought there was too much inconsistency in this virtual gallery.
7. I would imagine that most people would learn to use this virtual gallery very quickly.
8. I found the virtual gallery very awkward to use.
9. I felt very confident using the virtual gallery.

10. I needed to learn a lot of things before I could get going with this virtual gallery.
Additional Study-Specific Items
I was able to clearly view all the artworks present in this virtual gallery.
I was able to easily navigate through this virtual gallery.

Note. Items were scored on a 5-point scale (1 = *strongly disagree*, 5 = *strongly agree*). The items were presented in a random order.

In addition, the two questions explicitly about navigation and art viewing in the gallery were presented with the SUS but treated as separate, individual items during analysis (see Table 2.1). Participants were also asked what type of input device they used in the gallery (possible responses included *mouse*, *touchpad*, *touchscreen*, *trackpoint*, or *other*), and to report feelings of nausea, they responded, using a 1 (*No, not at all*) to 7 (*Yes, very strongly*) scale, to "Did you feel motion sick, dizzy, or nauseous from the virtual gallery?". Finally, participants were invited to leave open-ended feedback or comments regarding their experience.

Results

Data Processing and Reduction

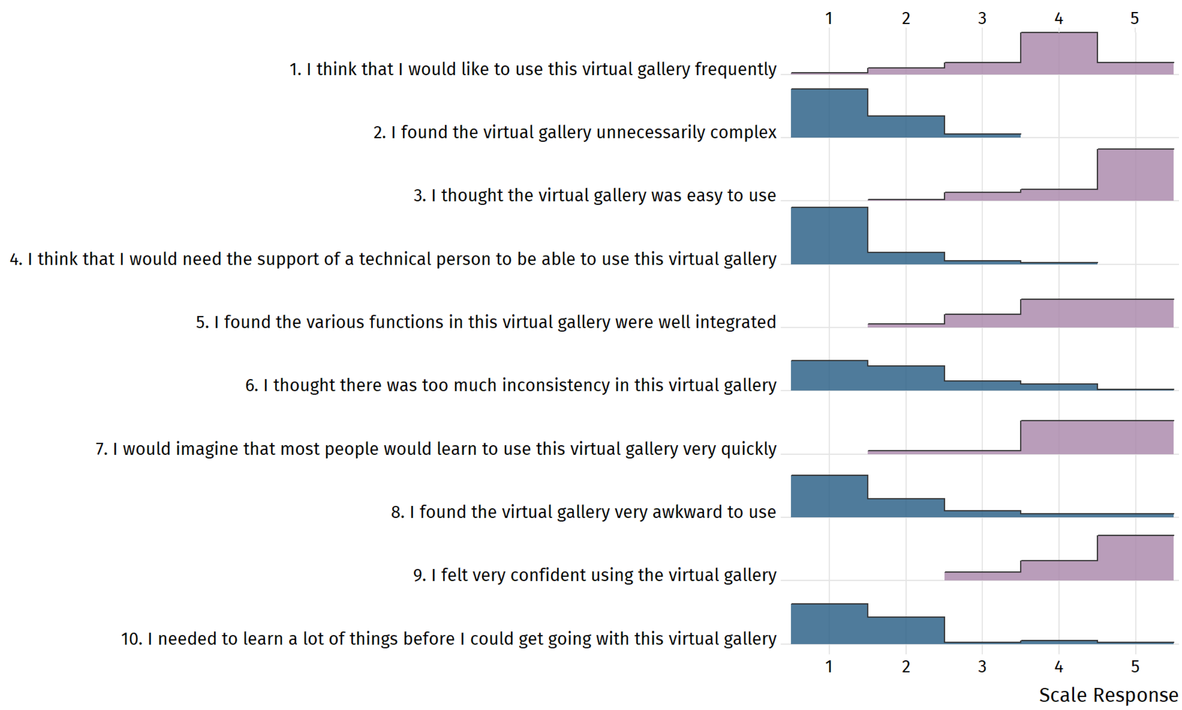
Data processing and statistical analyses were conducted in R 4.1 (R Core Team, 2021). Out of the 61 participants who began the study, 4 participants dropped out mid-study and didn't complete the entire Qualtrics survey, and their data were excluded from analysis. Participants were also excluded if they failed a directed response item embedded in the gallery usability survey (*n* = 3 excluded for this reason). These eliminations left 54 participants who were then processed for gallery performance quality. After careless in-gallery behaviors, indications of abnormal loss of connection, and poor browser performance were assessed, we were left with a final sample of 44 participants from 10 different countries. The 10 participants who were dropped during processing for performance quality can be broken down further: one person experienced total gallery failure with no known cause; one person was dropped for being unable to control their gaze due to using a nonstandard input device instead of a mouse (this participant clicked “other” when asked about their input device and had no recorded movements in their gaze data); and eight people were eliminated for slow movement speed (there are various reasons, from browser-specific issues, to high nausea, why this may have occurred).

Once data processing was complete, analysis was conducted using the R packages *psych* (Revelle, 2021), *reghelper* (Hughes, 2021), and *parameters* (Lüdecke et al., 2020). Gender responses were coded as binary (female = 1, male = 0). In addition, mouse input devices were recoded as binary (mouse = 1, all other input devices = 0) to better reflect our choice to design the gallery explicitly for mouse usage. Nausea, SUS scores, maximum movement speed, total visit and artwork viewing times, and distance traveled within OGAR were explored in the Pearson’s *r* effect size metric, using guidelines of .10/.30/.50 to represent small, medium, and large effect sizes respectively (Cumming, 2012). For categorical participant factors like gender and whether they were using a mouse as their input device, we used Cohen’s *d*, which can be interpreted in terms of small, medium, and large effects using .20/.50/.80 as common benchmarks (Cumming, 2012).

Usability

We started by evaluating OGAR’s usability through feedback on the SUS and accompanying measures. The SUS had high internal consistency reliability (Cronbach’s α = 0.89) that was in line with previous work using the scale (Lewis & Sauro, 2009). On average, participants gave OGAR a good SUS rating (*Mdn* = 87.50 out of 100, *M* = 82.90, *SD* = 14.64, range from 37.50 to 100). Both the median and mean were higher than the common benchmark score of 80 used to mark good system usability (Lewis, 2018).

Figure 2.2. SUS Item Score Distributions

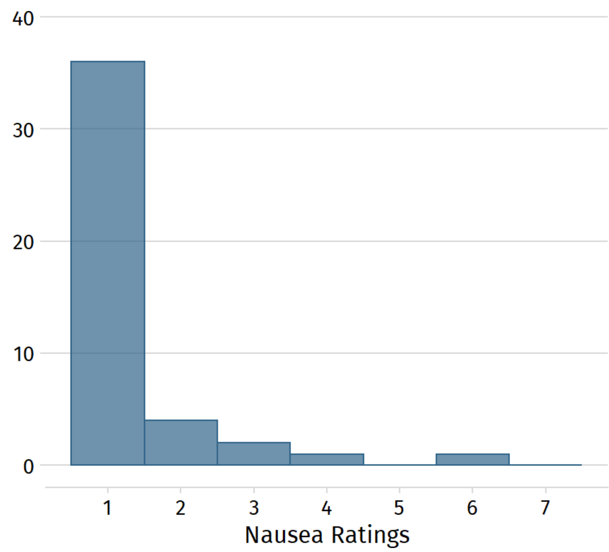


Note. The figure displays the scores in their original 1-5 response scale (i.e., prior to reverse-scoring and rescaling).

To provide a more granular view of participants' usability experience, Figure 2.2 displays a ridgeline plot of the ratings for all 10 SUS items (on their original 1-5 response scale used by the participants). The item-level distributions show that, for seven of the 10 items, the modal rating reflected the highest usability option.

To supplement the classic SUS questions, we asked participants whether they were able to clearly view the artworks present in the gallery (*Mdn* = 5.00, *M* = 4.57, *SD* = .79) and easily navigate through the virtual gallery (*Mdn* = 5.00, *M* = 4.55, *SD* = .76). The high scores at the ceiling of the response scale suggest good usability for these specific aspects of the gallery.

Figure 2.3. Distribution of Nausea Ratings



Note. The figure displays participant ratings for the item "Did you feel motion sick, dizzy, or nauseous from the virtual gallery?" on a scale from 1 (*No, not at all*) to 7 (*Yes, very strongly*).

Usability ratings were high on average but exploring variability in usability ratings can give insight into likely predictors of usability experiences. One particularly interesting factor is the experience of nausea. As Figure 2.3 shows, nausea ratings were very low, and notable nausea occurred in only a small portion of our sample (only 4 participants provided nausea ratings of 4 or greater out of 7; *M*= 1.36, *SD* = .97). Ratings of nausea had a modest correlation with SUS scores (*r* = -.23 [-.49, .07], *p* = .136), reflecting lower usability ratings as nausea increased. We suspected that poor gallery functioning may have contributed to the nausea experienced by some participants, so we examined whether there was a correlation between nausea and maximum movement speed as a proxy of overall gallery functioning; no such relationship was found (r = .09 [-.21, .38], p = .559).

Because OGAR was designed for use with a mouse in mind but data collection for the current study depended on the personal equipment of our online participant pool, the relationship between input device and usability is important to consider. Participants who used a traditional mouse in lieu of other alternatives gave non-significantly higher overall SUS ratings than those who did not (d = .24 [-.40, .86]). The SUS items regarding desire to use the virtual gallery (d = .61 [-.06, 1.26]), finding the gallery unnecessarily complex (d = -.40 [-1.03, .25]), feeling confident using the virtual gallery (d = .37 [-.27, 1.00]), and needing to learn a lot of things before getting going with the gallery (d = .52 [-.14, 1.17]) conveyed relatively stronger effect sizes for mouse usage.

These average scores on the SUS and additional usability questions represent the bulk of user experiences. Most user feedback was positive—something that is reflected in open ended feedback. Many participants wrote that they enjoyed their experience, "nearly felt like [they] were there," and that OGAR was "the easiest [virtual space] to use that [they've] encountered so far." Some participants also provided commentary about their subjective experiences with the artworks: "It was great to see some abstract paintings and some of them were really made me think a lot." Collecting open-ended feedback from our participants also allowed us to hear any specific problems they encountered and additions or changes to the gallery that they would be interested in seeing in the future. For example, one participant's comment that "the art closer to the right of the screen were harder to see and navigate to" within the square gallery condition may imply that the artwork on the right wall, relative to the starting location, may have been too small for adequate viewing on smaller screens by a diverse audience. We also learned that some participants would prefer navigation and exiting instructions available after entering full-screen mode, or that other participants are interested in the ability for in-gallery behaviors that mimic videogames (e.g., a sprint mode) or other applications they often use. All comments can be viewed on OSF (https://osf.io/f9e8d/).

Behavior in the Virtual Gallery

Following our second aim—appraising the validity of OGAR as a research tool—the position and gaze data collected within OGAR allowed us to identify whether patterns in participant behavior align with expected behavior in physical spaces. Linear regression models were used to examine predictors of participant behavior; the reported effects are standardized (β). For comparisons using categorical predictor variables, such as room condition (one room = 1, two rooms = 2) and mouse use (did not use mouse = 0, used mouse = 1), and continuous outcomes, we reported *Y*-standardized regression coefficients, noted as β_Y, in which only the outcome variable is standardized (Long, 1997, chap. 2). The coefficients of these regressions are equivalent to Cohen's *d* effect sizes or the difference, in *SD* units, in the outcome between both groups (Long, 1997). Descriptive statistics for each room condition can be found in Table 2.2.

Table 2.2. Descriptive Statistics for each Room Condition

	One Room		**Two Room**	
	M (*SD*)	*Mdn*	*M* (*SD*)	*Mdn*
Visit Duration (*s*)	76.32 (55.44)	63	174.16 (178.23)	116
Distance Traveled (*m*)	35.79 (23.05)	36.43	102.48 (48.23)	88.62
SUS Total Score	83.29 (16.63)	90	82.60 (13.28)	87.50

Note. Participants were randomly assigned to the one room (n = 19 [9 women, 10 men]) or the two room (n = 25 [10 women, 15 men]) condition.

Visit Duration

On average, people spent about 76 seconds in the one-room condition and 174 seconds in the two-room virtual gallery (see Table 2.2). Thus, in line with our core hypotheses about validity, time spent in OGAR was significantly greater for the two-room gallery condition than the one-room condition (β_Y = .67 [.08, 1.25], p = .026). Time spent in the gallery was not significantly related to nausea severity (β = .11 [-.20, .42], p = .465) or to SUS scores (β = .06 [-.26, .37], p = .719). People who used a mouse spent slightly less time in the gallery, but not significantly so (β_Y = -.33 [-.97, .32], p = .311). In sum, visit length was greater when OGAR presented more rooms, and comfort and usability had non-significant relationships with the time that people chose to spend in the gallery.

Distance Traveled

What factors affected the distance people traveled within the gallery? As expected, participants traveled further in the two-room condition than in the one-room condition (β_Y = 1.30 [.83, 1.77], $p < .001$), supporting one of our core hypotheses about validity. In addition, people who spent more time in OGAR traveled a further distance within the gallery (β = .69 [.46, .92], $p < .001$). Finally, total distance traveled within the gallery was only weakly and non-significantly related to nausea level (β = .15 [-.15, .46], p = .320), overall SUS score (β = -.09 [-.40, .22], p = .540), or mouse use (β_Y = .14 [-.51, .79], p = .661).

Engagement with the Artworks

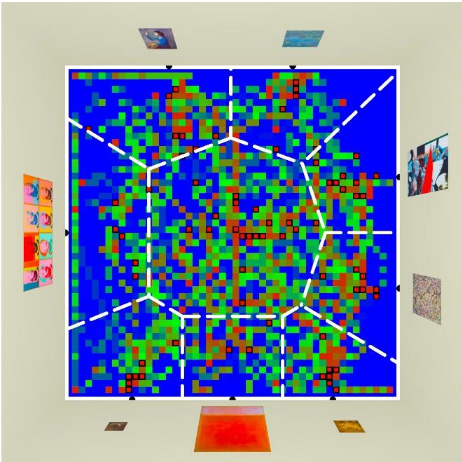
Our third aspect of validity—whether people actually approached and engaged with the artworks—was examined descriptively using heatmaps overlaid with regions of interest relevant to each artwork. Heatmap density was calculated via time-stamped X and Y position data for each participant as they explored the gallery and was weighted evenly for each participant. This ensures that every participant contributed evenly to the heat map density. In addition, density at the starting location for entering the gallery was omitted to prevent any visible heat spiking that is irrelevant to deliberate participant movement. Finally, the heatmap underwent histogram equalization to optimize the global contrast of our data and enhance the level of visible detail in our mapping. Regions of interest were defined by partitioning the floorspace of the gallery into Voronoi cells that comprise a larger diagram (Voronoï, 1908). Each cell represents the region of the gallery that is closer to the center of that cell's artwork than to any other. Once the Voronoi diagram is overlaid on the heatmap, any intense clusters of participant movement should be visible within a specifiable artwork region. Note that this exploratory data visualization method does not yield any inferential statistical tests, but because it is data-driven, it is robust and fully reproducible.

Figure 2.4 illustrates the resulting heatmap with overlaid Voronoi regions. Artworks (to scale) with black points at the center of each image are placed on the walls for reference. Areas of red are the "hottest," representing places where the participants spent the most time. Areas of the highest density have additionally been outlined in black for visual clarity.

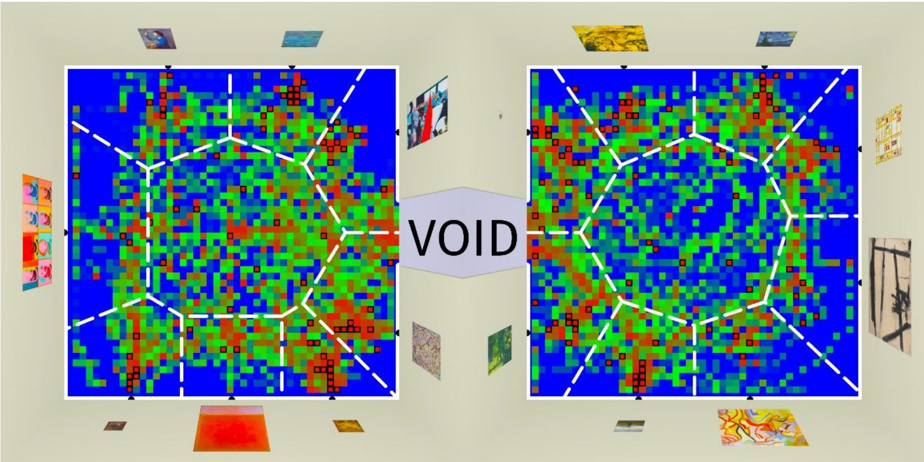
The diagrams for both room conditions clearly reveal "hot spots" clustered in front of the artwork's center that are most often within the Voronoi region defined by each artwork's location. This indicates that participants' movement within the gallery is purposeful and consistently guided by the artworks, as it ought to be. Additional Voronoi regions with sporadic hot spots can be seen surrounding the center of each room and can be thought of as highly trafficked movement areas or common pathways around the gallery as opposed to destinations of interest.

Figure 2.4. Heatmaps of One-Room and Two-Room Conditions with Voronoi Region Overlays

A



B



Note. The area marked VOID on Figure 2.4B represents the doorway between rooms in the two-room condition. No hallway or area exists at this designation—it's a result of the converging bird's-eye viewpoints.

Illustrating Some Options and Opportunities for Researchers

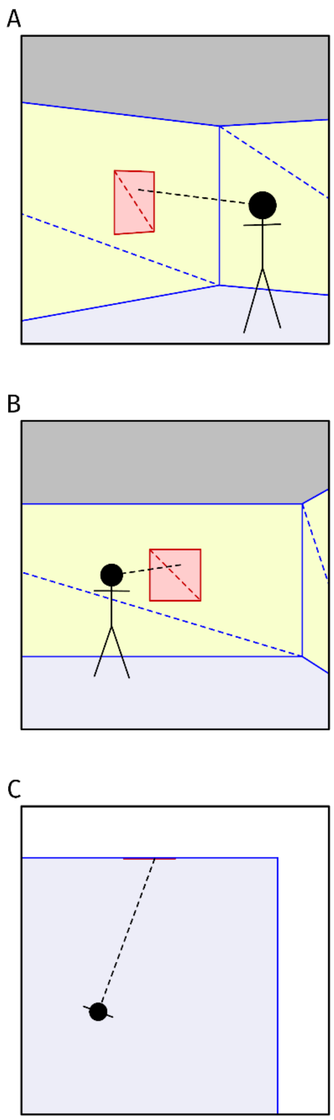
As noted in the Introduction, several available virtual gallery programs have different useful characteristics but have not been coalesced into a tool ideal for research use. Extending our discussion of OGAR past its usability and basic features seems helpful to show what researchers can do with the virtual gallery. These remaining findings are intended to demonstrate some functionality that might spark ideas and give food for thought for researchers interested in using OGAR.

Viewing Time

Viewing time—how long people spend looking at an artwork—is a major outcome in art and aesthetics research (Carbon, 2017; Pelowski et al., 2017). Studies of free-viewing behavior in museums commonly show that visitors spend much less time viewing an image on a wall than many would think—often between 8 to 20 seconds (Reitstätter et al., 2020; Smith & Smith, 2001; Smith et al., 2017)—in light of how impactful people later describe the experience (Smith, 2014).

Viewing time is easy to obtain from OGAR. Since every movement and gaze that the participant completes within OGAR is recorded, we can take advantage of existing gallery infrastructure to automatically code what artwork a participant is examining at any given point in their visit in a low-level viewing analysis. To do this, we created a parallel program for view determination that operates on a viewpoint, defined by the set eye height and avatar location within the gallery, and gallery definition (see Figure 2.5). To figure out what a ray extending from that viewpoint would hit first (i.e., what a person is “viewing”), every artwork and wall segment are turned into two triangles each, forming a rectangle. Then, a Möller-Trumbore intersection (Möller & Trumbore, 1997) is applied between every triangle and a line defined by the viewpoint. The shortest distance intersection is kept as the view target. If no triangle intersects, the view determination is “None.” View behavior can be coded as a binary *yes* (1) or *no* (0) for viewing artwork or categorically assigned with the corresponding artwork, given that participants are viewing an artwork at a given timestamp.

Figure 2.5. Multiview Representation of View Determination



Note. Three views of an illustrative scene involving a user avatar (stick figure) viewing an artwork (red). The dotted line emanating from the avatar's head indicates the direction that the user is looking in the gallery. In this scene, the ray drafted from the avatar's head is tested for intersections against triangles that compose the walls and artworks. The center of the view ray intersects with the upper-right triangle composing the red artwork. Therefore, this hypothetical user, at this point in time, is determined to be viewing the red artwork. Panels 5A and 5B show this interaction from two third-person perspectives. Panel 5C represents the projection of this scene as a "bird's eye view," which makes the intersection with the artwork more readily apparent.

As an example, Table 2.3 lists the average viewing times for each artwork in the two-room version of the OGAR gallery used in the current study. (We focus on the two-room condition because it has the largest number of artworks.) Overall, gallery visitors in this condition viewed an artwork for a mean of 5.92 (*SD* = 2.40) seconds, which falls on the lower end relative to research on artwork viewing time in real-life museum environments. More broadly, people in the two-room condition spent a little over half their time looking at artworks (*M* = 94.74 seconds) as opposed to other features of the space (i.e., walls, or nothing; *M* = 80.64 seconds).

Viewing Distance

Another common measure of interest to museum researchers is viewing distance: how far away, in meters, visitors stand from a work when viewing it (e.g., Clarke et al., 1984; Carbon, 2017; Estrada-Gonzalez et al., 2020). Perhaps unsurprisingly, research conducted in unconstrained field settings commonly finds that viewing distance increases as the artwork size increases. In OGAR, viewing distance in meters can be measured by taking the coordinate location of each avatar at each timestamp that a participant is viewing an artwork and calculating the distance between the location coordinate and the artwork coordinate. Then, viewing distance measurements can be averaged for each participant and the entire sample for each artwork present (see Table 2.3). To draw once again from the two-room condition of the present study for an example, participants viewed artworks at an average of 2.04 meters (*SD* = 1.26), although viewing distance varied considerably by artwork (range: 0.71 to 5.81 meters).

Table 2.3. Viewing Behaviors for the Two-Room Condition

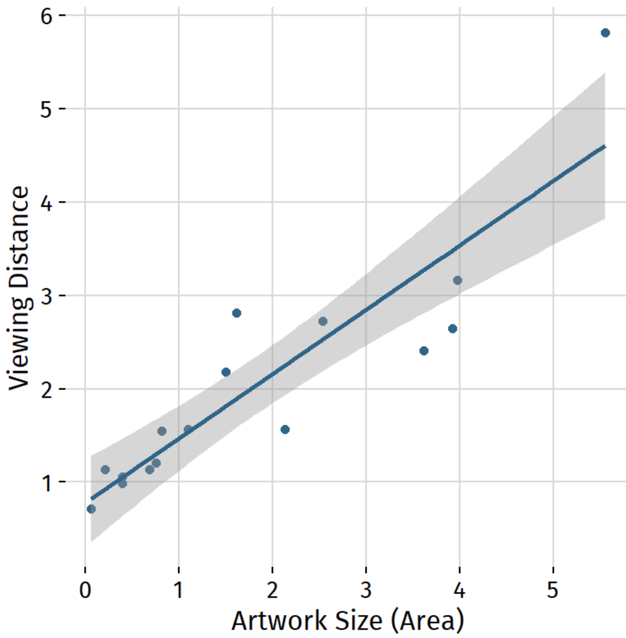
	Viewing Time (s)		**Viewing Distance (m)**	
	M	*Mdn*	*M*	*Mdn*
Non-Art Gallery Elements				
Viewing Nothing	11.46	5.60	NA	NA
Viewing Wall	69.18	47.60	NA	NA
Art Images				
Lita Curtain Star	5.89	3.60	3.17	2.44
Woman with a Fan	5.04	3.20	1.55	1.14
Water Lilies	5.07	2.00	1.21	0.97
Untitled (Green and Red; *FR*)	5.62	2.80	2.73	2.17
Terrano X	12.70	4.40	1.57	1.29
Starry Night	6.10	1.40	1.13	0.88
Broadway Boogie Woogie	4.33	3.40	2.81	1.82
Painting Number 2	9.66	5.00	5.81	3.11
Untitled (*WK*)	5.61	2.60	2.41	1.89

Solitary Tree	6.90	3.40	0.98	0.71
Untitled (*PK*)	4.38	1.40	1.56	1.37
Eyes in the Heat	6.73	3.60	2.18	1.54
Reclining Girl	4.22	2.80	1.05	0.98
Untitled (*MR*)	4.27	2.40	2.64	2.35
The Silver Goblet	5.86	2.00	1.14	0.67
Hare	2.36	0.40	0.71	0.49

Note. Details about the artworks are in the Appendix. Viewing times are reported in seconds; viewing distances are reported in meters. Untitled works are followed by artist initials in italics for ease of identification.

This picture-to-picture variation in viewing distance, it turns out, is a function of image size. In the virtual gallery, viewing distance was strongly correlated with artwork area ($r = .90$ [.73, .96], $p < .001$). As Figure 2.6 depicts, people viewed larger artworks from farther away and smaller artworks from close up, just as visitors typically do in real-world galleries (Carbon, 2017; Estrada-Gonzalez et al., 2020).

Figure 2.6. Relationship Between Artwork Size and Viewing Distance

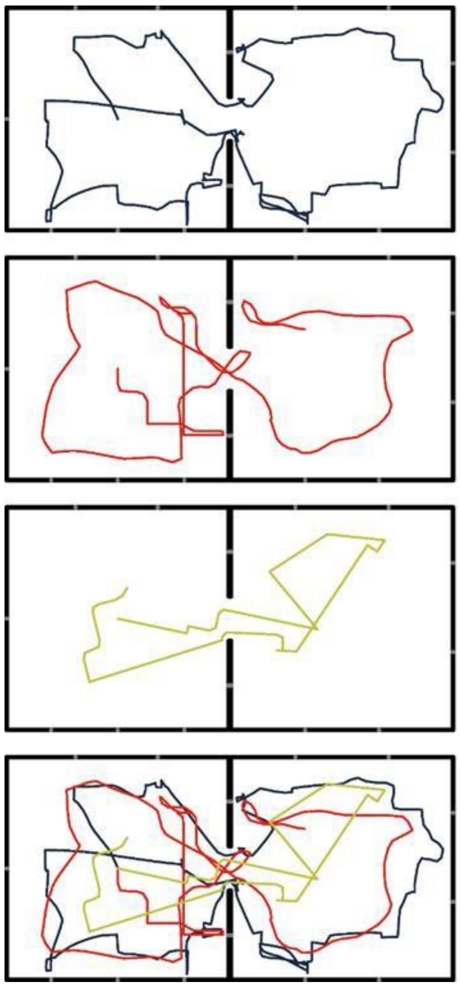


Navigation and Movement Trajectories

In addition to viewing behaviors, participant navigation is a common outcome in field studies of museum visits (Tinio & Specker, 2020; Tröndle, 2014): the paths people take as they move through a gallery is interesting in its own right but also practical knowledge for curators and museum professionals. Within OGAR, researchers can similarly explore how people navigate and interact with virtual gallery spaces. Using the participants' coordinates across time, researchers can identify the temporal qualities of movement in the virtual gallery.

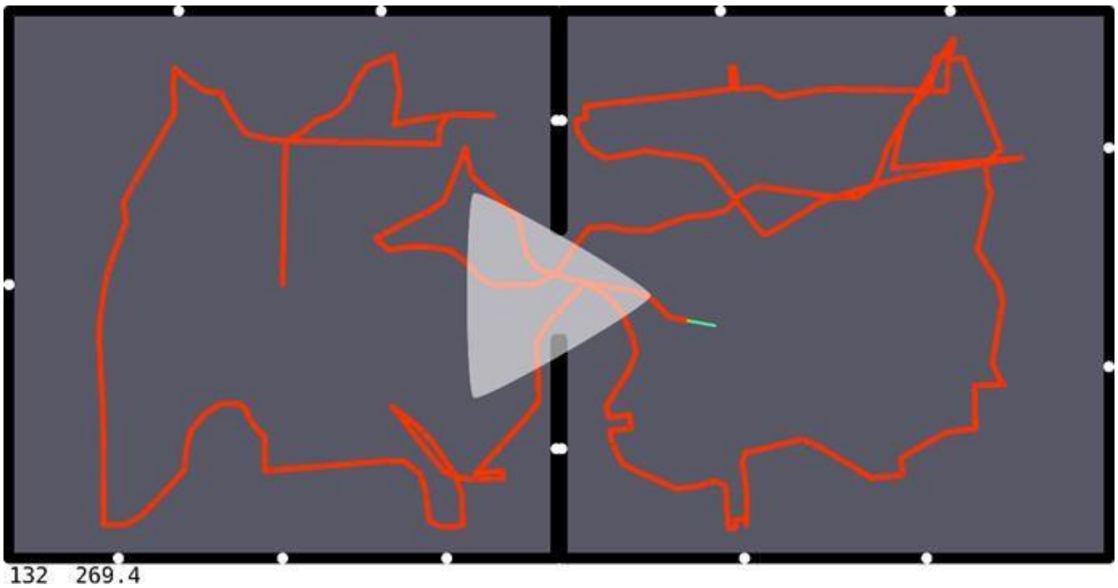
For example, Figure 2.7 displays the movement trajectories of three representative participants who were randomly assigned to the two-room condition (top 3 panels) as well as a combined overlay (bottom panel). Although all participants started at the same position, they took different routes through the gallery, explored different rooms first, covered varying amounts of ground, exited the gallery at different spots, and showed differences in trajectory features like the straightness of their path. Researchers interested in movement and trajectory analysis could find the data provided by OGAR fertile.

Figure 2.7. Individual Navigation Trajectories for Three Participants in the Two-Room Gallery (top 3 panels) and the Overlaid Patterns (bottom panel)



Going beyond a static snapshot of a participant's movement, we can animate the path a person takes around the gallery. This provides in-depth temporal information for a single person and is an intuitive, holistic way of presenting dense position and viewing data. As an example, Figure 2.8 links to an animated video of a single participant's time spent in the virtual gallery. The red line traces their movement; the small green line indicates their gaze direction.

Figure 2.8. An Animation of a Single Participant's Time Spent in the Virtual Gallery



Note. The image links to a video stored on Open Science Framework (https://osf.io/63rsz/). The red line indicates movement; the small green line indicates gaze direction. The animation is played at 3x speed.

Discussion

In the present research, we developed and evaluated the Open Gallery for Arts Research, or OGAR, as a tool for exploring the psychology of virtual gallery encounters. In contrast to the current landscape of offerings, OGAR is an affordable, flexible, and extensible open-source tool for creating virtual art gallery spaces and measuring participants' behaviors within it. A proof-of-concept study was conducted to assess the usability and performance of OGAR in an online sample of adults.

First, the usability of OGAR appears to be strong based on results from the SUS, additional gallery-specific usability questions, nausea ratings, and open-ended feedback. Average SUS ratings were high (*Mdn* = 87.50 out of 100), beyond the threshold of 80 commonly used to indicate good system usability (Lewis, 2018). Variance in SUS scores were related in coherent ways to other factors. The small portion of the sample with elevated nausea ratings gave lower SUS ratings, and using an input device other than a mouse, the system's optimal input, was likewise associated with lower SUS ratings.

Second, the behavior of participants within the virtual gallery was coherent and predictable, resembling what researchers observe in participants navigating real-world gallery spaces. Using the position and gaze data collected within OGAR, we were able to support the view that our online participants were interacting with the virtual gallery in the ways that researchers in the psychology of museum experiences would expect. People who were randomly assigned to a gallery that was twice as large and contained twice as many artworks, for instance, spent a much longer amount of time in the virtual gallery and traveled a much greater distance. While not shocking, such findings show that participants were interacting with the gallery as one would expect. In addition, as evidence that participants used the gallery to view the artworks, heatmaps of the gallery floorplan partitioned into Voronoi regions for each artwork clearly show high densities of participant movement clustered in front of each artwork along with commonly trafficked paths between artworks. These key findings suggest that the OGAR system produces basic participant behavior that is psychologically coherent and similar to gallery behavior in traditional in-person settings (Tinio et al., 2015).

Finally, we sought to illustrate how OGAR can be applied and extended for future research use. We showed how a participant's movement trajectory through the gallery can be identified and visualized, which could be useful for researchers interested in how environmental and curatorial factors influence how people move through gallery spaces (Bourdeau & Chebat, 2001; Tröndle, 2014). In addition, we showed how viewing data can be used to obtain measurements of viewing time and viewing distance, two outcomes of long-standing interest to researchers studying how people view art in museums (Carbon, 2017; Estrada-Gonzalez et al., 2020).

Extensions and Options

OGAR is a versatile tool that affords a wide range of opportunities. Researchers can extend OGAR or alter its configuration to fit their specific needs by varying any of the following:

- Gallery layout (i.e., size and configuration of gallery walls)
- Artworks (i.e., image choices, sizes, placement)
- Aesthetics (i.e., floor, ceiling, and wall colors)
- Avatar characteristics (eye height, acceleration, maximum speed).

In addition, OGAR's licensing allows researchers to make more extensive changes to OGAR's software if they wish. Doing so opens the possibility for additional features like audio, in-gallery pop ups, randomization features, or any number of add-ons that a researcher may desire for their work. Changes and additions to the OGAR software can be shared with GitHub pull requests. Updates to OGAR and further details are available on GitHub at https://github.com/mboerwinkle/OGAR .

Behaviors such as artwork viewing time and viewing distance can be recreated using avatar height, gallery layout specifications, and participant movements collected during data collection. These measurements can then be analyzed in relation to researcher-set design features of the gallery like artwork choice, curation, or layout of the virtual space. They can also be examined alongside additional surveys or other measurement tools that can easily accompany OGAR in platforms like Qualtrics. This particularly opens up the possibility of deeper examination of subjective experiences as opposed to the behavioral measures focused on in the current paper. Further, data can be animated to show navigation trajectories in OGAR that can be analyzed qualitatively, examined in terms of artwork regions defined by Voronoi cells, or simply examined between participants. Also of interest, OGAR output may serve as a suitable proxy for mobile eye tracking. Although bounded by the edges of a monitor, unconstrained position and gaze movement within the environment allow participants a high degree of visual exploration during their visit.

Some Practical Issues

A common problem with many virtual environments, videogames, simulations, or other applications using a first-person viewpoint in 3D environments is visually-induced motion sickness (Kennedy et al., 2000; Keshavarz & Hecht, 2012; Stoffregen et al., 2008). To guard against nausea or motion-sickness-prone participants in the present study, we provided brief warnings in the study's Prolific recruitment ad and consent form. In addition, we asked people to exit the virtual space should they feel dizzy, nauseous, or motion sick during participation. Nausea ratings were quite low in our study, but because these represent the scores of only those people who completed the study to that point and not those who dropped out or who declined to take part due to likely nausea, our data probably underestimates the base rates of nausea experiences in OGAR. We recommend including warnings about motion sickness during participant screening as well as measuring ratings of nausea experienced during participation, which are useful for analyses of participant behavior and for possible exclusions. Further, because some motion sickness is inevitable for studies employing virtual galleries and similar tools, these precautions are important for both ethical treatment of participants and overall data quality.

As with all online tools, the OGAR Client has issues to be addressed related to compatibility between different participants' computer environments. Incompatibility can occur for many reasons, but non-standard web browsers (e.g., outdated, poorly configured, or simply non-compliant) are a major source. In addition, old, underpowered, or otherwise overloaded computer systems can contribute to poor behavior, as with any system that relies on real-time input. Although it is desirable for all participants in online studies to have similar experiences, in practice there is no way to ensure a perfectly identical experience for everyone when research is conducted on personal machines. As such, the best a team of researchers can do is to carefully weigh the values of control and flexibility for a particular aim. For this study, we chose to control hardware and software by dictating that participants must use a desktop or laptop computer with a non-Safari browser. We did not, however, mandate any more stringent hardware requirements like amount of RAM needed, screen resolution, or graphics processor attributes, or require that participants download or have access to specialized software. These initial specifications simply sought to eliminate clearly incompatible participants.

After data collection was complete, a second line of standards was used to determine what level of performance would be considered acceptable. Thresholds for performance based on mouse movements, maximum speed, and event reporting were established to eliminate some participants post data collection. Again, although some level of performance is required for useful data collection, it is not necessary to eliminate every participant who possibly was on the edge of compatibility, and the least strenuous thresholds that are acceptable should be placed to avoid over-filtering the data. Mechanisms for measuring software performance for the current study are discussed further in the introduction, but future iterations of OGAR will likely improve on these by adjusting minimum speed requirements and recording participant frame rate.

Ultimately, however, many of these concerns can be sidestepped by using OGAR on lab-operated computers. If the Client is operated on a lab-operated computer, then near total compatibility can be achieved.

Getting Started with OGAR

Individuals interested in using OGAR can view relevant documentation about getting started as well as other details about the project on its GitHub (https://github.com/mboerwinkle/OGAR). Recommendations for server set up, new OGAR releases, community contributions, and other relevant commentary will be updated regularly as the project continues its development. Interested parties can follow the page to receive notification of any related changes. The authors also welcome correspondence should readers have additional questions about OGAR or require additional support.

Conclusion

Developing virtual alternatives to traditional in-person field research in the arts has the potential to make both basic research and applied assessments of art engagement (e.g., by people working in visitor studies, art education, and museum curation) more affordable, accessible, and safer during public health crises. OGAR may find use with the arts researcher looking for a way to transcend the research-design limitations of physical museum spaces and ever-changing needs of experimental design, with the curator who needs a cost-effective, time-effective way to collect data on curatorial choices for upcoming exhibitions, or with the museum studies class that requires a safe and accessible way for students to engage with gallery spaces without leaving the classroom—all while achieving an acceptable degree of similarity with real-life experiences.

CHAPTER III: VISITING VIRTUAL MUSEUMS: HOW PERSONALITY AND ART-RELATED INDIVIDUAL DIFFERENCES SHAPE VISITOR BEHAVIOR IN AN ONLINE VIRTUAL GALLERY

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Rodriguez-Boerwinkle, R. M., & Silvia, P. J. (2023c). Visiting virtual museums: How personality and art-related individual differences shape visitor behavior in an online virtual gallery. *Empirical Studies of the Arts*, 02762374231196491. https://doi.org/10.1177/02762374231196491

The rise of the use of digital tools, such as virtual art galleries, by art museums is opening new opportunities for both art engagement and research into the psychology of art. On the side of the museum visitor, virtual environments may hold unique appeal and affordances for online users, relative to traditional in-person visits to art museums. This implies that visits to virtual galleries may be in some ways distinct from traditional in-person experiences and highlights the need to further explore psychological experiences of visitors to these virtual art spaces. On the side of the researcher, virtual gallery tools may be beneficial for extending research that is challenging to conduct in physical museum environments (Rodriguez-Boerwinkle et al., 2023b). These digital tools appear promising for understanding the psychology of both traditional museum visitors as well as the emerging study of online museum visitors.

In the present research, we explored how personality can be reflected in encounters with art in the context of museums, using an online, virtual art gallery simulation tool that allows participants to visit researcher-designed art galleries. We examined how a broad range of personality traits and art-related individual differences predict many aspects of visit behavior—

including how long people visited the gallery, the distance they traveled within it, how much of their visit time was spent viewing art, and how long and from what distance they viewed each artwork—in the virtual gallery space. Taken together, this project illustrates how individual differences affect virtual visit experiences and provides a model for how virtual gallery tools can lend insight into virtual vistorship.

Virtual Visits to Museums

Interest in online museums has grown considerably as increases in technological accessibility, concerns about health and safety in public spaces, and a general zeitgeist of open cultural sharing over the internet have come to define the first quarter of the 21st century. Art museums, in particular, have turned to virtual gallery tools to cultivate online visitors. There are likely a few reasons for these efforts.

First, virtual galleries offer accessibility to a broader population of visitors who might not otherwise have the opportunity to visit physical institutions due to geographic, temporal, physical, or other accessibility constraints. As such, virtual galleries can potentially provide a platform for arts researchers and museum personnel to collect data from a larger and more diverse population of visitors, which can be used to evaluate and expand museum services to include and promote interest in a wider net of visitors. Specifically, virtual gallery tools may, through their broader reach in audience, increase awareness of and access to exhibitions and collections. Further, virtual gallery tools can provide valuable feedback for institutions through exposure on social media and other digital channels, which helps museums better understand their audiences and improve their programming.

Second, art museums have likely increased their use of virtual gallery tools, because of the unique opportunities afforded by their auxiliary features. One class of these features is participatory and allows visitors to engage with the digital content in manner that is not possible within the confines of physical museum spaces. For example, virtual galleries may implement commenting forums (Grincheva, 2018), supplemental viewing features (Cotter et al., 2022b; Cotter et al., 2023a), or online games and contests (*Rijksmuseum Masterpieces Up Close*, n.d.) that promote engagement with the virtual environment. The other class of features is evaluative and can be used to aid researchers and applied personnel in investigating visitor interactions with digital spaces. For example, virtual galleries meant for research can be equipped with additional content and tools like associated text or HTML-based questions, audio clips, and chat rooms. Further, the unique environmental and analytical additions offered by virtual galleries are of interest to the Human-Computer Interactions community, and research in this area suggests that the technological affordances of virtual gallery spaces have distinct psychological benefits (Lee et al., 2019; Sundar et al., 2015; Sylaiou et al., 2017). Overall, the increase in use of virtual gallery tools by museums—undergirded by their increased accessibility and additional affordances—signals an emerging new context for aesthetic experiences that is, as of yet, understudied.

Personality and Visit Behavior

Personality factors, particularly openness to experience, have strong ties to aesthetic experience (Silvia et al., 2015; Silvia & Nusbaum 2011) and artistic knowledge, interests, and activities (Atari et al., 2020; Chamorro-Premuzic et al., 2007, 2009; Furnham & Walker, 2001; Schwaba et al., 2018; Swami & Furnham, 2014). In contrast to the massive body of lab and survey work on personality and the arts, however, only a handful of studies have explored visitors' personality traits and their relationships with museum visit behaviors and experiences (Mastandrea et al., 2009; Meyer et al., 2023; Rodriguez et al., 2021).

Contemporary personality research commonly emphasizes broad traits, such as the Big Five (Digman, 1990; Goldberg 1993) or HEXACO models (Lee & Ashton, 2004). Personality traits are commonly measured with long self-report scales like the NEO PI-3 (240 items; McCrae & Costa, 2007) and the HEXACO PI-R (100 items; Lee & Ashton, 2006) that capture broad traits and their specific facets. The breadth and scope of common tools for personality measurement yield rich information, but at a cost of brevity and convenience. The length and complexity of the typical personality inventory—and even their fairly long short forms (e.g., 60 items)—make them challenging to use in field research.

In a study of personality and art museums, Mastandrea et al. (2009) compared people who chose to visit museums of modern art versus museums of ancient art using the openness to experience factor of the NEO and the experience seeking subscale of the Sensation Seeking Scale (Zuckerman, 2007). They found that although the two groups didn't differ in openness to experience, modern-art visitors scored higher in experience seeking than ancient-art visitors. A recent study explored facets of openness to experience in a large sample of visitors to German museums for science, technology, and cultural history (Meyer et al., 2023). The visitors completed a brief openness to experience scale and reported how often they had visited different kinds of museums—including art museums—in the past year. The facets of openness to experience more strongly predicted the frequency of visiting art museums than visiting museums devoted to science and history. Finally, in a study of emotional diversity, visitors higher in openness to experience reported greater emotional balance among the set of emotions they felt during their time in an art museum (Rodriguez et al., 2021).

Virtual museums offer some unique opportunities for studying personality. The small literature to date shows that personality is relevant to visitor behavior but can be challenging to assess in the field. In particular, personality scales can be impractically long for visitors who are graciously taking time from their visit to participate in the research project. Researchers have tried to address this challenge in several ways. For example, Rodriguez et al. (2021) recruited two participant branches—community museum visitors and university students—so that lengthy self-report scales could be administered to the student group in the lab before they visited the museum. Other researchers have narrowed their scope to include only the most salient personality factors for their project (e.g., openness to experience and sensation seeking; Mastandrea et al., 2009) and employed short forms (e.g., scales with 4 items per facet; Meyer et al., 2023). Many researchers have alternatively focused on demographic variables such as gender, age, or training in the arts that are quick to collect in a field setting (Brieber et al., 2014). Shifting the research environment from field studies of off-the-street visitors to online environments of virtual visitors affords expanded time and opportunities for personality assessment.

But beyond practical issues of assessment, virtual art galleries are interesting contexts for studying personality's role in art engagement in their own right. As museums look to expand their virtual presence and understand their online visitors, it's important to learn more about who tends to engage with online art galleries and how aspects of the visitors shape how they visit the virtual spaces. Just as real-world art museums are more appealing to some people than others, virtual art environments are probably more appealing based on visitor personality. For instance, introversion has been linked generally to internet usage, because online platforms serve as a space in which some introverted individuals feel encouraged to convey their genuine selves and participate in activities they enjoy (Amichai-Hamburger et al., 2002; Ebling-Witte et al., 2007). Similarly, virtual galleries may offer an environment where people with some personality characteristics or other individual differences feel more comfortable or more readily engage in art viewing.

Psychological Research on Museum Visit Behaviors

The psychological study of art viewing in museum or gallery contexts is wide ranging (Pelowski et al., 2017; Smith, 2014), but three popular topics are particularly relevant to the present research: how long visitors spend viewing an artwork (viewing time), how long people spend in the museum (visit time), and how close or far they stand to an artwork (viewing distance).

At times you may need to use landscaped pages for large tables or figures that normally will not fit within left and right margins. Follow these steps for all landscaped pages. An example landscape page is on page 16.

Viewing and Visit Time

Viewing time is a major variable in museum-based psychological studies of art. For example, viewing time has been examined in terms of how it affects outcomes like visit satisfaction and museum fatigue (Specht, 2010), and how it is affected by factors like social interactions with other visitors (Tröndle et al., 2012) or the length of labels that accompany the artworks (Smith et al., 2006, 2017; Specht, 2010).

People vary widely in how long they examine an artwork, but by far museum visitors spend a short time viewing individual paintings (Smith, 2014). In a study of viewing time within the Metropolitan Museum of Art, Smith and Smith (2001) found that people spend a mean time of 27.2 s viewing a work of art, with a median time of just 17.0 s. Fifteen years later, Smith et al. (2017) replicated this effect at the Art Institute of Chicago with a larger sample and a more diverse set of artworks. This effort yielded remarkably similar results: there was a mean viewing time of 28.63 s and a median time of 21.00 s. Even shorter viewing times were observed in two discrete data collection periods within the Belvedere Museum in Vienna, with artworks including both painting and sculpture (M_1 = 15.44 s, M_2 = 14.93 s; Mdn_1 = 8.58 s, Mdn_2 = 8.07 s; Reitstätter et al., 2020). Notably, similar viewing times to Smith and Smith (2001) and Smith et al. (2017) were reported by Carbon (2017), who used human judges to time participants. Similar viewing times between Reitstätter et al. (2020) and Estrada-Gonzalez et al. (2020) were also recorded—both using mobile eye tracking equipment.

In addition to time spent viewing individual works, the overall duration of the visit is an important metric of visitor behavior. Its obvious practical value to curators and museum professionals aside (e.g., Brida et al., 2017), visit duration is a complex and interesting psychological outcome that is tied to people's motives for visiting, the context of the visit (e.g., if they are alone), and their experiences during the visit (Smith, 2014). In a sample of off-the-street visitors to an art museum (Cotter et al., 2022a), for example, the duration of the visit was correlated with several outcomes (e.g., whether the visit was relaxing or satisfied their curiosity). More time is not necessarily better, as an experiment that manipulated visit time found. Aeschbach et al. (2022) randomly assigned visitors to spend either 10, 45, or 110 minutes in a gallery. The visitors' subjective ratings of whether the visit was too short, too long, or ideal were only loosely coupled to the actual time spent, and "subjective time" appeared more important as a predictor of the restorative quality of the visit.

Viewing Distance

Viewing distance—how far or close someone stands when viewing an artwork—has received less attention than viewing time from arts researchers but is an important aspect of visitors' viewing behavior. In an early study, Clarke et al. (1984) varied the projection size of a set of art images and asked participants to view the images from whatever distance “looks best” or felt the most “comfortable.” In both conditions, participants chose to stand further from larger artworks than smaller ones. Decades later, Carbon (2017) found that the effect held with a high positive correlation between artwork area and viewing distance using real artworks in a gallery environment.

More recently, Estrada-Gonzalez and colleagues (2020) examined viewing behaviors, including viewing distance, in an art museum using mobile eye tracking equipment and expanded the literature on viewing distance with the most in-depth examination to date. In addition to further replicating the effect of image area on viewing distance, they found that viewing distance was predicted by formal image properties (e.g., Shannon entropy and amplitude spectrum slope). Together, these studies showed that preferred viewing distance increases as artwork size increases, along with other factors that have received less attention.

Challenges with Assessing Time and Distance

Quantifying visit behavior is at the core of understanding visitor experience and central to exhibition evaluation (Yalowitz & Bronnenkant, 2009), but much of it relies on coarse assessment methods. For example, studies that use human observers and manual timing (e.g., stopwatches) for participant behaviors like viewing specific artworks, stops at exhibitions, or overall visit duration run into two problems: human error and time intensiveness. Smith and Smith (2001) noted problems with determining when an artwork viewing began and, although they were able to collect an adequate sample size, they limited their data collection to just six artworks out of the Met’s collection. Later, Smith et al. (2017) and Carbon (2017) both used human timers (and judges of viewing distance in the latter case), and similarly only had the personnel to collect data on less than 10 artworks.

Using Virtual Galleries as a Tool for Research

Virtual art galleries designed by researchers are one way to mitigate some of the measurement challenges posed by museum visit behaviors. In addition to being robust to somewhat subjective and coarse measurement approaches, non-immersive 3D environments—those viewed on single screens, such as desktop PCs, as opposed to immersive virtual reality environments—are widely accessible. Users need only have access to standard PCs, and researchers can collect visitor data on lab computers or the participant's own equipment.

The current study uses the Open Gallery for Arts Research (OGAR; Rodriguez-Boerwinkle et al., 2023b), an online virtual gallery tool for studying the psychology of the virtual art museum visit. The open-source gallery software allows researchers to design a non-immersive 3D environment and embed it in a webpage or online survey software where it can then be accessed by participants recruited through online survey pools or by lab-based participants with lab hardware. OGAR is designed to have minimal user constraints, so it is suitable for use on a diverse range of equipment. The gallery spaces that one creates with OGAR are highly customizable, so researchers can design the environment to fit their needs—even going so far as making basic recreations of real spaces.

On the side of the user, the aspect ratio of the gallery is set to 16:9. The resolution of the virtual space is dependent on the specifications of the participant's hardware, and the gallery is configured to refresh at the device's refresh rate (typically around 60 fps). The participant avatar is rendered with a first-person view of the gallery with movement that can accelerate to 1.8 m/s.

OGAR collects and allows the designer to access a robust set of time-stamped variables about the user, such as their movement and gaze, and it has been evaluated as a tool for studying navigation and artwork viewing behavior. In a proof-of-concept study using a sample of 44 adults, Rodriguez-Boerwinkle et al. (2023b) demonstrated some basic indicators of OGAR's validity: as the gallery size increased, visitors spent longer in the gallery and traveled further within it. The participants actively approached and viewed the available artworks, and they were able to successfully navigate the space without major usability concerns. Finally, although the number of participants and images was small, the findings for artwork viewing times and viewing distances resembled findings from artwork viewing studies in real spaces (i.e., viewing times were generally brief, and visitors viewed larger artworks from further away).

The Current Study

The aim of the current study is two-fold. First, it serves as an advanced proof-of-concept of the usability and validity of OGAR, a new tool for studying virtual visitors. As the first study of its kind, Rodriguez-Boerwinkle et al. (2023b) served as a valuable early exploration into the use of non-immersive 3D virtual galleries for psychology of arts research, but there is still much to learn about this new tool. For example, OGAR's inaugural study was conducted using only a small sample and was likely underpowered to detect some effects. The one- and two-room layouts used by Rodriguez-Boerwinkle et al. (2023b) also constrained participants to relatively predictable, linear paths. In the present study, we examined unconstrained movement and view behavior in a three-room, interconnected gallery space with more artworks and a much larger participant sample than what was used in Rodriguez-Boerwinkle et al. (2023b). The larger sample and the larger, interconnected room layout will allow for greater variability in participant movement and corresponding visit behavior.

Second, this project examines the roles of personality and other individual differences in virtual museum visit behavior. We focused on two categories of individual differences. First, personality was examined in terms of the Big Five personality traits: neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness. Second, art-related characteristics also stood out as promising correlates of visit behavior, so we included measures of subjective art knowledge (Smith & Smith, 2006) and aesthetic responsiveness (Schlotz et al., 2020). Aesthetic responsiveness is a relatively new construct, but art knowledge has a long history in lab and field research. The original aesthetic fluency scale (Smith & Smith, 2006) was developed in the field using samples of museum visitors, and the early validation work found that people with higher art knowledge, not surprisingly, had more training in art and art history and visited art museums more often.

Thus, in the current study, we explored the relationships between personality and individual differences and virtual visitors' behaviors, such as overall visit time, artwork viewing time, artwork viewing distance, and total distance traveled within the gallery. We expected that high levels of openness to experience, high subjective art knowledge, and high aesthetic responsiveness would be associated with indicators of overall visit engagement, such as visiting the virtual gallery for longer and traveling further in the gallery, as well as with viewing individual artworks for longer. Based on past work on preferences for representational and abstract artworks (e.g., Belke et al., 2006; Feist & Brady, 2004; Van Paasschen et al., 2015), we also hypothesized that people high in openness to experience and in art knowledge would show relatively greater engagement with abstract works. We also expected prior findings about artwork size and viewing distance—people viewing larger images from farther away—to replicate in this virtual gallery. Beyond these general expectations, the analyses were exploratory and intended to serve as a first look at how personality and individual differences predict virtual visit behaviors.

Methods

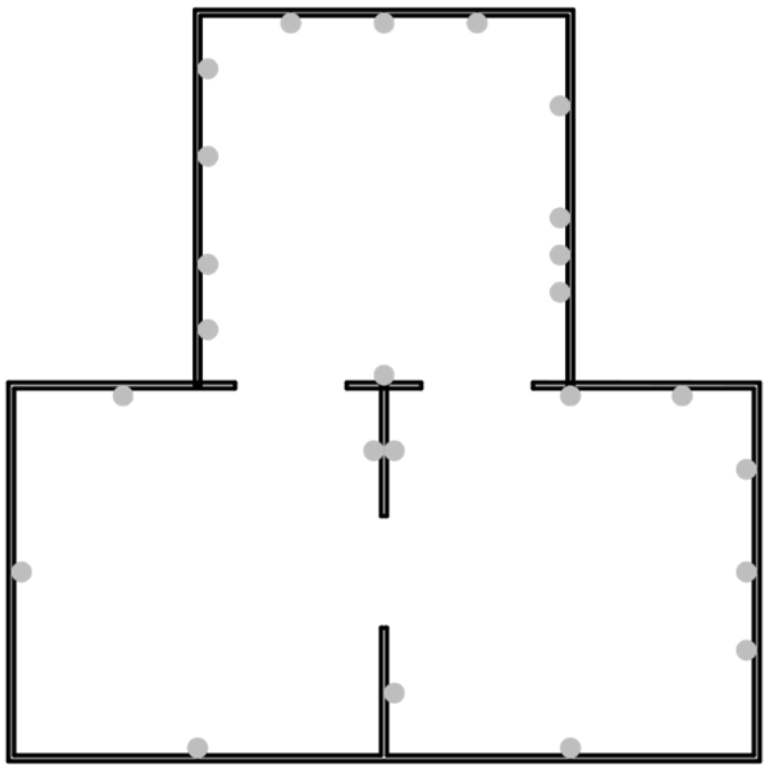
Participants

A total of 320 adult online participants were recruited from the Prolific.co survey panel. The recruited sample size was based on a power analysis for detecting key effects of at least r = .20. To be eligible, participants were required to be native English speakers between the ages of 18 to 70, to reside in predominantly English-speaking countries (Australia, Canada, Ireland, New Zealand, UK, USA), and to have completed at least 10 studies on Prolific.co with a minimum study approval of 95%. In addition, devices were restricted to desktop or laptop computers only. After the target sample size was collected, participants were screened for careless responding, drop-out, and technology issues (described later), which yielded our final sample size of 264 people (age M = 33.8 years, SD = 12.3, range from 18 to 69; female-identifying: 41.3%). Participants were paid a flat amount of USD $3 regardless of the duration of time in the gallery. All participants provided informed consent, and the project was approved by the UNCG Institutional Review Board (#21-0311).

Procedure and Apparatus

The present study was conducted in a Qualtrics online survey with an embedded instance of OGAR. After responding to some basic demographic questions—age, country of residence, and gender—and assessments of personality and arts knowledge, participants were directed to a survey page containing OGAR (for a detailed description of virtual galleries produced by OGAR, see Rodriguez-Boerwinkle et al., 2023b). Participants were allowed to visit the space for as long as they wished; when they finished, they were able to exit the virtual gallery and continue their Qualtrics survey, which concluded with post-visit questions about their experience.

Figure 3.1. Gallery Floorplan



Note. Floorplan measured in meters. Gray dots indicate artwork locations.

Gallery Definition and Artworks

The gallery definition outlines the parameters of the gallery space and includes information about walls, environment textures, and artworks. For this study, we designed a three-room gallery layout where visitors were free to pass into any room from any other room. Rooms were identically set at 10 m × 10 m with a total gallery floor area of 300 m^2. Artwork choices, sizes, and placements were also defined in the gallery definition (see Figure 3.1; a sample video is available at Open Science Framework: https://osf.io/6q5t3/). All artworks were shown in their "true size" in the gallery (i.e., proportional to the meter-based gallery environment).

Twenty-four artworks were selected from the Vienna Art Pictures System (VAPS; Fekete et al., 2022) for use in the current study. VAPS is a comprehensive dataset of 999 art images developed for research in empirical aesthetics. The chosen artworks span historical period, genre, style, content, and size. The artworks were selected with the constraint that the set was evenly split between representational and abstract works, given the importance of that variable in people's art preferences (Belke et al., 2006; Feist & Brady, 2004; Van Paasschen et al., 2015). Further, artworks were chosen to ensure that they were high enough resolution to meet the viewing demands of the virtual gallery and to avoid significant differences between the mean artwork area in square meters for the representational (M = 1.22, SD = 1.40) and abstract groups (M = 2.18, SD = 2.57), $t(22) = -1.14$, $p = .268$, $d = -.48$ [-1.29, .33]. A complete artworks list for this study can be found in Table A2.

Pre-visit Assessments

Participant demographics, including age, gender, and country of residence, were recorded during the survey. Responses to gender were coded as binary (female = 1, male = 0, other responses = missing). Additionally, browser information was collected for the purposes of debugging the OGAR system, if necessary, and wasn't analyzed. Before people visited the virtual gallery, they completed measures of personality, art knowledge, and aesthetic responsiveness.

Personality

Broad personality traits were measured with the NEO-3 Five Factor Inventory (McCrae & Costa, 2007). The 60-item inventory uses a five-point scale (from *strongly disagree* to *strongly agree*) to measure neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness. While all five factors are relevant to art and aesthetic experience, openness to experience has particularly strong relationships with art knowledge, art interest, and nuanced emotional responsiveness to the arts (Feist & Brady, 2004; McCrae, 2007; Silvia, 2007; Silvia et al., 2015). In the present study, reliability for the NEO was high: the factors had Cronbach's alphas of α = .92 (N), α = .85 (E), α = .79 (O), α = .75 (A), and α = .89 (C), respectively.

Art Knowledge

Art knowledge was assessed with an updated version of the Aesthetic Fluency Scale. The original scale, introduced by Smith and Smith (2006), uses domain-specific knowledge about the arts to gauge *fluency*, or art expertise (Atari et al., 2020; Cotter et al., 2023b; Silvia, 2007), by asking participants how familiar they are with 10 topics and individuals from art history. The Revised Aesthetic Fluency Scale (Cotter et al., 2023c) uses the same approach but has a wider scope. It includes 36 items with a simplified three-point response scale ranging from 0 (*I don't really know anything about this artist or term*) to 2 (*I know a lot about this artist or term*). This scale showed good reliability with the current sample (α = .95).

Aesthetic Responsiveness

As a final pre-visit assessment, participants completed the English version of the Aesthetic Responsiveness and Engagement Assessment (AREA; Schlotz et al., 2020). Using 14 items with statements like "I am deeply moved when I see art," the AREA asks participants to indicate their levels of aesthetic appreciation, intense aesthetic experience, and creative behavior on a five-point point scale ranging from 0 (*Never*) to 4 (*Very Often)*. Researchers can form an overall aesthetic responsiveness score or sort the items into three highly correlated subscales: aesthetic appreciation (e.g., "I notice beauty when I look at art"), intense aesthetic experience (e.g., "When I look at art, my heart beats faster"), and creative behavior (e.g., "I write poetry or fiction"). We opted for the overall aesthetic responsiveness score in the present research (α = .91).

Post-visit Assessments

Directly after completing their virtual gallery visits, participants were asked, “Did you feel motion sick, dizzy, or nauseous from the virtual gallery?” on a scale from one (*No, not at all*) to seven (*Yes, very strongly*). Although uncommonly endorsed by participants, high levels of nausea experienced might indicate motion sickness related to movement in the virtual space. In Rodriguez-Boerwinkle et al. (2023b), nausea ratings were related to lower user experience in OGAR and may further be a sign of poor gallery performance or low data quality.

Visit Behavior

Participants navigated the virtual gallery by using the W, A, S, and D keys or the arrow keys on their keyboard to move forward, left, back, and right; they used their mouse to control their gaze direction. These controls are standard in online gaming applications (Whitty et al., 2010) and allow for full range of view and movement within the space. As participants visited the virtual gallery, OGAR collected movement data in the form of X and Y coordinates within the gallery floorspace and gaze data in the form of pitch and yaw (defined in terms of radians) every 200 ms. From these, several visit behavior variables were constructed.

Visit Time

Visit time—the total time in seconds that someone spends in the virtual gallery—was quantified as the total time between when participants entered and exited OGAR’s fullscreen mode within Qualtrics (accounting for if they did so multiple times).

Distance Traveled

Since the gallery definition is scaled in meters, each one-coordinate shift in X or Y represents a change of 1 meter of distance within the gallery. Thus, distance traveled was calculated with the following equation, where *i* represents the second position in the coordinate chain and *n* is the total number of points in the path that the user took through the gallery:

$$\sum_{i=2}^{n} \sqrt{(y_i - y_{i-1})^2 + (x_i - x_{i-1})^2} \ .$$

Artwork Viewing Time

Artwork viewing time is another obtainable variable in OGAR. The predetermined eye height of the participant's avatar and avatar's location within the gallery form a viewpoint, and artwork locations (any space within the artwork's area) define possible viewing targets. Then, the shortest distance intersection was calculated between the viewpoint and the viewing target. In this sense, one can imagine a ray in the direction of the participant's recorded gaze pitch and yaw extending from the location of the avatar's "eyes" (at the X and Y location of the avatar location on the gallery floorspace and the Z location indicated by the set eye height) to the closest straight-line gallery feature (wall, floor, ceiling, or artwork). If the intersection was within the parameters of an artwork—as opposed to other gallery features— the view behavior was coded as a binary *yes* (1) and the corresponding artwork was assigned to the view at that timestamp. Timestamps that consecutively view an artwork with no more than one 200 ms gap in view assignment were summed to arrive at a single chunk of viewing time in seconds. Participants may choose to view an artwork more than one time during their visit, so to arrive at the operationalization of viewing time used in the current study, every instance of an artwork view by a single participant was summed.

Artwork Viewing Percentage

Artwork viewing time was also examined globally by calculating the percentage of total time spent in the gallery that was spent looking at artworks as opposed to other features (e.g., walls, floors, and ceiling). This allows for a measure of artwork viewing time that is not conflated with the total time that someone spends in the gallery.

Artwork Viewing Distance

Finally, at each timestamp where a person is viewing an artwork, the distance between the coordinate for the viewed artwork and coordinate location of the avatar was calculated to obtain a measure of artwork viewing distance in meters.

Results

Screening, Data Reduction, and Analysis Approach

The data and analysis files are available at Open Science Framework (https://osf.io/6q5t3/). The data were screened and cleaned in R 4.1 (R Core Team, 2022). We applied a set of exclusion checks for technological (e.g., wrong device or poor system performance) and behavioral (e.g., inattentive responding on the self-report scales) reasons. The full details of the exclusion criteria and process are provided in the online supplemental material. Of the 320 Prolific participants recruited for this study, no participants were excluded for inattentive or careless responding on the self-report scales. Fifty-six participants were excluded for a variety of technical reasons, such as static avatars and markers of poor browser performance. Of the 56, 18 were omitted because they didn't visit at least two of the three rooms. The overall exclusion rate was 17.5% for a final sample of 264 participants.

Time spent visiting the gallery was measured in minutes; distance traveled was measured in meters. The global art viewing percentage was calculated as the ratio of cumulative time in seconds spent viewing any artwork to the cumulative time in seconds visiting the gallery. For the purposes of the current analyses, visit time, distance traveled, and the art viewing percentage were transformed to be more normally distributed via ordered quantile normalization (Peterson & Cavanaugh, 2020). An overview of descriptive statistics and correlations for these raw values, participant information, and results for each scale can be found in Table A3. Correlations for continuous variables are reported in the Pearson's *r* metric, which can be interpreted as small (.10), medium (.30), or large (.50) effects (Cumming, 2012). For categorical variables, the Cohen's *d* metric is used with benchmarks of .20 for small, .50 for medium, and .80 for large effects.

Between-person predictors of gallery behavior were examined using structural equation models estimated in Mplus 8.1 with maximum likelihood estimation and robust standard errors. To streamline the analyses, the individual differences were grouped into two models: the first model had global personality traits (the five NEO factors as latent factors), and the second had arts-specific predictors (the aesthetic fluency and AREA scales as latent factors). Indicators of each latent variable, except for aesthetic responsiveness[1], were created by randomly assigning each associated scale item to a parcel. This resulted in each latent factor from the NEO scale model having four indicators of three items each. The latent variables of aesthetic fluency and aesthetic responsiveness were assigned four parcels of nine items and three parcels of a varying number of items, respectively, within the art-specific predictor model. Reported structural regression results are fully standardized with respect to X and Y variables. Separate univariate models were run for each outcome (visit time, distance traveled, and percentage of time spent viewing artworks).

Confirmatory factor analyses (CFA) of the measurement models were conducted to evaluate model fit. A model representing the NEO scale had the following fit indices: χ^2 (160, *N* = 264) = 354.19, $p < .001$, Root Mean Squared Error of Approximation (RMSEA) = 0.068 [90%

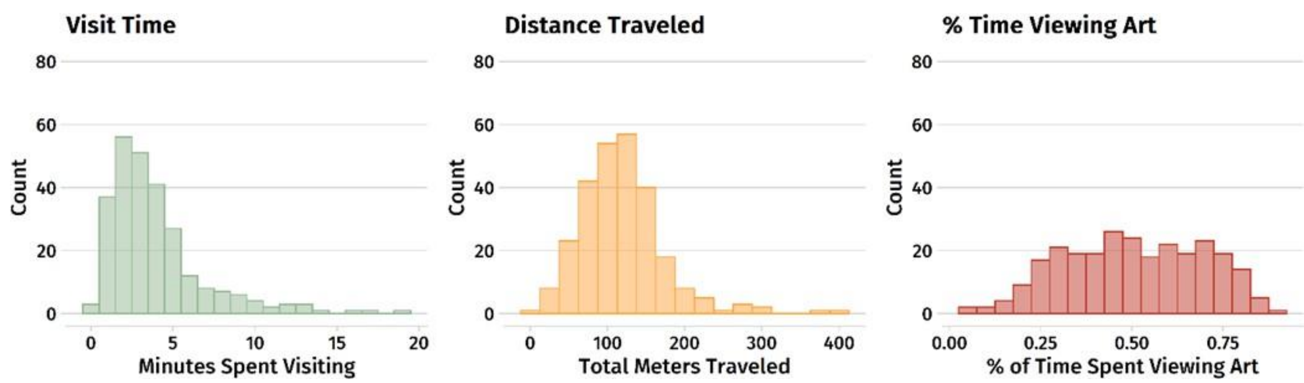
[1] Indicators of aesthetic responsiveness were assigned based on the *a priori* subscales present in the AREA survey. Two of the indicators (aesthetic appreciation and intense aesthetic experiences) load very highly on the aesthetic responsiveness latent factor because they share an item (Schlotz et al., 2020).

CI: 0.058, 0.077], Comparative Fit Index (CFI) = 0.924, Tucker-Lewis Index (TLI) = 0.909, Standardized Root Mean Squared Residual (SRMR) = 0.071, suggesting adequate model fit. Model fit for the art-specific predictors was also reasonable (χ^2 (13), N = 264) = 52.61, $p < .001$, RMSEA = 0.107 [90% CI: 0.078, 0.139], CFI = 0.970, TLI = 0.952, SRMR = 0.058). Figures that illustrate these CFA models are in the online supplemental material associated with this manuscript.

What Did People Do in the Virtual Gallery?

We first explored overall gallery behavior in the sample, using visit time, distance traveled, and percent of visit time spent viewing artworks as behavioral indicators of visit experience. Figure 3.2 displays the distributions of these outcomes. As shown in Table A4, people tended to spend about 3.91 (*SD* = 3.00) minutes visiting the gallery and traveled about 118.83 (*SD* = 55.50) meters. The two measures were highly correlated: $r = .70$ [.63, .76], $p < .001$, but individual experiences varied greatly. Participants tended to view artworks during about 51% (*SD* = .19) of the visit time, but this measure achieved an almost uniform distribution (see Figure 3.2). The percentage of time spent viewing art was also positively correlated with visit time ($r = .17$ [.05, .28], $p = .006$) and distance traveled ($r = .22$ [.11, .34], $p < .001$), respectively.

Figure 3.2. Distributions of Visit Time, Distance Traveled, and Art Viewing Time Percentage



Note. Scores are shown in their raw metric. For the analyses, transformed versions of visit time, distance traveled, and the percentage of time spent viewing art were used.

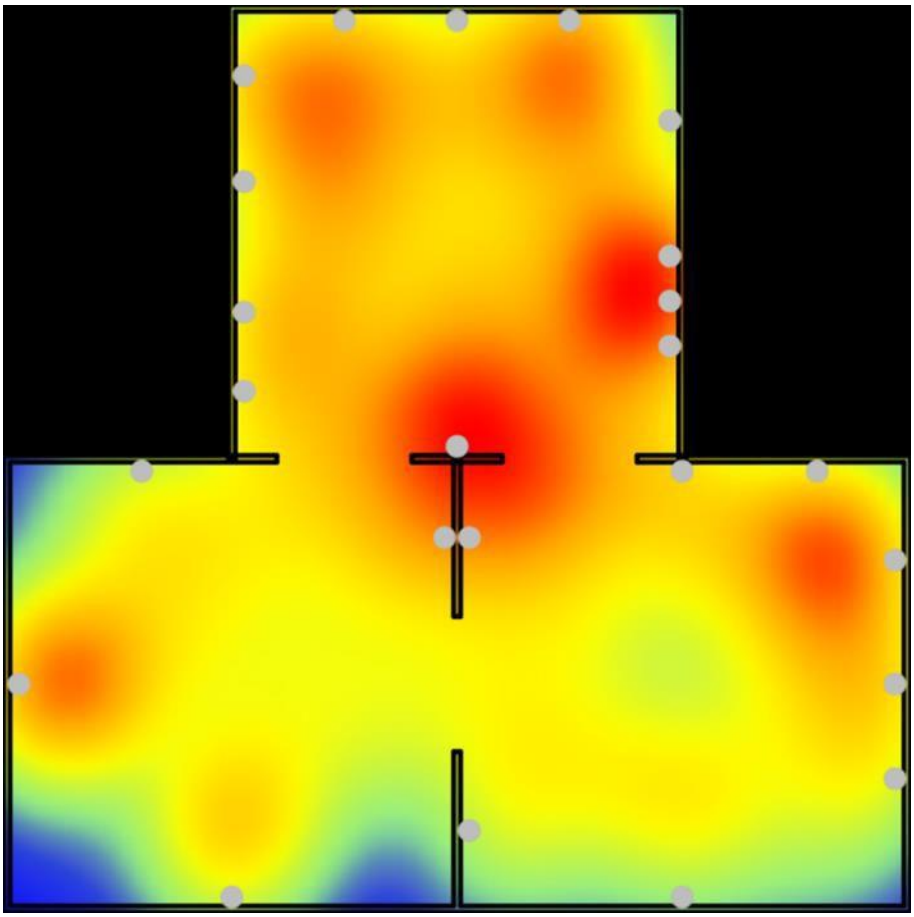
Some of the variance in gallery behavior could be explained by age differences. Older participants, for instance, tended to spend longer (r = .31 [.20, .42], p < .001) and travel further (r = .19 [.07, .30], p = .002) in the virtual gallery, but they spent a smaller proportion of time viewing artwork (r = -.40 [-.50, -.29], p < .001).

Gallery behaviors also varied by gender. Although there was no difference in distance traveled between women and men (d = -.01 [-.26, .24]), women tended to visit the gallery for longer than men (d = .26 [.01, .51]), and they had lower art viewing percentages than men (d = -.40 [-.65, -.15]).

In addition to more art- and navigation-focused between-person behaviors, nausea was measured immediately after the visit. On average, participants had very low nausea levels (M = 1.49, SD = 1.10). While nausea had no relationship with time spent or distance traveled in the gallery, it did have a modest, negative correlation with percent of time spent viewing art (r = -.22 [-.34, -.11], p < .001), suggesting that those who experienced greater levels of nausea spent less of their visit time actively viewing artworks.

Global gallery behavior can be illustrated using heatmaps of the virtual space. Figure 3.3 depicts the movement patterns of the total sample. The hot spots in front of the artworks reveal that participants spent relatively more time located in front of the images on the walls, as one would expect based on viewing behaviors in real-life gallery spaces. Although perhaps obvious, this pattern illustrates that people were in fact navigating the gallery to engage with the artworks instead of moving aimlessly or standing around.

Figure 3.3. Heatmap of Participant Movement



Note. This image is a to-scale, bird's-eye representation of the gallery space used in this study. Red areas denote more highly trafficked locations. Artworks are represented with gray dots, slightly offset from the walls for better visibility.

In terms of viewing specific artworks, the average OGAR visitor viewed about 18 out of 24 artworks (78%). Participants tended to view any given artwork for an average of 4.78 seconds (*SD* = 9.81), but this too varied widely between artworks. How far in meters a person chose to view an artwork from, or the viewing distance, averaged 2.43 meters but was also highly variable (*SD* = 2.08). For a full list of descriptive statistics related to individual artworks, see Table A3.

How Did Personality and Individual Differences Predict Gallery Behavior?

Taken together, the sample of virtual visitors showed gallery behaviors that were consistent with previous literature on viewer behaviors within real-world galleries and with our pilot study (Rodriguez-Boerwinkle et al., 2023b). The next natural step then, is to explore personality traits and art-related individual differences as predictors of variability in these gallery behaviors. Structural regression results using continuous predictors are reported as standardized effects (β), which can be interpreted like effect sizes in the *r* metric using the following guidelines: .10 for small effects, .30 for medium effects, and .50 for large (Cumming, 2012); *p*-values and 95% confidence intervals are reported alongside all effects. For each outcome, two models were run: one with the five NEO factors as predictors, and another with the two art-specific predictors (AREA and aesthetic fluency) as predictors.

Visit Time

How long did people visit the virtual museum? For the broad five-factor personality traits, extraversion ($\beta = -.29$ [-.43, -.16], $p < .001$) and openness to experience ($\beta = .27$ [.13, .40], $p < .001$) were the strongest predictors of time spent visiting the gallery, but in opposite directions: people high in extraversion were more likely to spend less time in the gallery, but those high in openness to experience visited for longer. Agreeableness ($\beta = .18$ [.04, .31], p =

.009) and neuroticism (β = -.18 [-.34, -.02], *p* = .028) also predicted visit time: more agreeable people spent longer in the gallery, but more neurotic people left sooner. Conscientiousness had no appreciable relationship with visit time (β = -.02 [-.16, .13], *p* = .842).

For the art-specific predictors of visit time, aesthetic fluency had a modest effect on time spent in the gallery (β = .18 [.02, .34], *p* = .028): people with higher art knowledge spent more time in the gallery. For the AREA scale, however, aesthetic responsiveness did not have any appreciable effect on visit time (β = .07 [-.09, .23], *p* = .395). The latent aesthetic fluency and aesthetic responsiveness factors had a correlation of *r* = .54 [.44, .63], *p* < .001.

Distance Traveled

How far did people travel during their gallery visit? Distance traveled in the gallery was predicted by extraversion, openness to experience, and agreeableness. Extraversion again had the largest correlation with this outcome: extraverted visitors traveled shorter distances (β = -.21 [-.36, -.07], *p* = .004). Participants who were high in openness to experience (β = .18 [.03, .33], *p* = .017) and agreeableness (β = .18 [.03, .33], *p* = .019), on the other hand, traveled further in the virtual gallery. Neuroticism and conscientiousness didn't significantly predict distance traveled (neuroticism: β = -.06 [-.23, .12], *p* = .526; conscientiousness: β = .02 [-.14, .17], *p* = .830).

For the art-specific predictors, neither aesthetic fluency (β = .11 [-.07, .28], *p* = .230) nor aesthetic responsiveness (β = .03 [-.13, .20], *p* = .695) had significant relationships with distance traveled.

Percent of Time Spent Viewing Artworks

While visiting the gallery, what proportion of people's time was spent viewing the art within it? Only openness to experience significantly predicted the percentage of visit time spent viewing artworks (β = .23 [.09, .37], *p* = .001): people high in openness to experience spent relatively more of their time in the gallery actively viewing artworks. None of the other NEO personality traits had significant effects (neuroticism: β = -.01 [-.20, .16], *p* = .908; extraversion: β = -.10 [-.23, .04], *p* = .170; agreeableness: β = -.08 [-.23, .07], *p* = .292; conscientiousness: β = -.03 [-.20, .13], *p* = .695).

For the art-specific predictors, neither aesthetic fluency nor aesthetic responsiveness was associated with the percent of time spent looking at art (aesthetic fluency: β = -.10 [-.25, .05], *p* = .181; aesthetic responsiveness: β = .05 [-.08, .19], *p* = .456).

How Did the Artworks Affect Picture-Level Viewing Behavior?

So far, we have explored how personality and individual differences predicted overall gallery behavior at the between-person level: the level of individual participants and their features (e.g., level of extraversion or openness to experience). The design, however, also has a within-person level: the level of individual art images and their features (e.g., their size and abstraction). Because viewing time and viewing distance were measured for each artwork people visited, we can explore questions about viewing time and distance at the within-person level as well. These models afford examining within-person main effects (e.g., how image size or abstraction predicts viewing time and distance) along with between-person main effects (e.g., how openness to experience predicts viewing overall distance) and cross-level interactions (e.g., if personality traits moderate the effect of image size on viewing distance). Aside from some clear expectations grounded in past work (e.g., viewing distance should increase with image size), these analyses were largely exploratory.

Multilevel models were used to examine how between-person individual differences (personality or art-specific predictors) interacted with within-person predictors of artwork characteristics (artwork area, abstraction) to predict within-person viewing behavior outcomes (viewing time, viewing distance) for a given artwork. These models were created using Mplus 8.1 with maximum likelihood estimation with robust standard errors. Four two-level models with random slopes were specified containing two within-person predictors (image size and image abstraction), between-person predictors (i.e., the five NEO traits in one model, and the two art-related factors in another), and their cross-level interactions. The personality and art-specific predictors were latent variables, as in the prior analyses, with standardized indicators. The within-person predictor variables (artwork area and abstraction) were within-person centered. One additional participant was excluded from this portion of the analyses (bringing the sample size to $n = 263$), because they did not view both representational and abstract images and therefore had no variance in this predictor. The intraclass correlations (ICC) were .26 for viewing time and .39 for viewing distance, so some variance (26% and 39%) was at the between-person level, but most of it (74% and 61%) was at the artwork level. The multilevel model results are reported as unstandardized regression weights (*b*). Higher values for image size indicate greater area (coded as m^2); higher values for image type indicate representational images (coded as .5) instead of abstract ones (coded as -.5).

Artwork Viewing Time

We first explored viewing time. For between-person main effects, personality had several main effects on the amount of time that a person chose to view an artwork. People high in extraversion viewed the artworks for significantly less time ($b = -1.50$ [-2.50, -.50], $SE = .51$, $p = .003$). People high in openness to experience, in contrast, viewed the artworks for significantly more time ($b = 1.72$ [.89, 2.54], $SE = .42$, $p < .001$). For the other traits, high neuroticism predicted marginally shorter viewing time, $b = -.99$ [-2.04, .06], $SE = .54$, $p = .065$, and no main effects appeared for agreeableness ($b = .32$ [-.53, 1.17], $SE = .43$, $p = .456$) or conscientiousness (*b* = -.51 [-1.49, .47], *SE* = .50, *p* = .305). In the model for art-specific predictors, there were no significant main effects on viewing time (aesthetic fluency: *b* = .25 [-.69, 1.19], *SE* = .48, *p* = .602; aesthetic responsiveness: *b* = .60 [-.18, 1.39], *SE* = .40, *p* = .130).

For within-person main effects, both predictors had significant effects on viewing time. People spent more time viewing relatively larger images (*b* = .75 [.65, .85], *SE* = .05, $p < .001$), and they spent relatively more time viewing the representational works than the abstract ones (*b* = 2.04 [1.57, 2.51], *SE* = .24, $p < .001$).

Finally, for interactive effects, openness to experience interacted with artwork features to predict viewing time. As openness increased, the relationship between area and viewing time became stronger (*b* = .26 [.13, .38], *SE* = .07, $p < .001$): people high in openness to experience were more strongly affected by image size when deciding how long to view an image. The other personality traits had no interactive effects with area (neuroticism: *b* = -.14 [-.30, .03], *SE* = .09, *p* = .113; extraversion: *b* = -.11 [-.24, .02], *SE* = .07, *p* = .101; agreeableness: β = .00 [-.14, .14], *SE* = .07, *p* = .974; conscientiousness: *b* = -.04 [-.20, .13], *SE* = .08, *p* = .660).

Openness to experience also significantly moderated the effect of abstraction on viewing time (*b* = .53 [.06, 1.00], *SE* = .24, *p* = .027). Representational artworks more strongly increased viewing time among people high in openness to experience. Notably, this interactive effect ran contrary to our expectation that people high in openness would show relatively more engagement with abstract works. Extraversion had the opposite moderating effect (*b* = -.75 [-1.37, -.14], *SE* = .32, *p* = .017); the positive effect of representational artwork on viewing time was stronger for introverted people and weaker for extraverted ones. None of the other personality traits had significant interactions (neuroticism: *b* = .02 [-.88, .93], *SE* = .46, *p* = .959; agreeableness: *b* = .27 [-.29, .82], *SE* = .28, *p* = .347; conscientiousness: *b* = .43 [-.41, 1.27], *SE* = .43, *p* = .317).

The art-specific variables had no significant interactions for viewing time. They didn't moderate the effect of artwork size (aesthetic fluency: *b* = .01 [-.16, .18], *SE* = .09, *p* = .916; aesthetic responsiveness: *b* = .10 [-.03, .24], *SE* = .07, *p* = .136) or artwork abstraction (*b* = .55 [-.23, 1.33], *SE* = .40, *p* = .170; *b* = -.06 [-.53, .40], *SE* = .24, *p* = .788).

Artwork Viewing Distance

We estimated similar models for viewing distance. First, for between-person main effects, openness had a significant negative effect (*b* = -.36 [-.56, -.17], *SE* = .10, *p* < .001). People high in openness were more likely to approach artworks more closely and view them from a shorter distance. Extraversion had a positive effect on viewing distance, *b* = .24 [.00, .48], *SE* = .12, *p* = .050: extraverted visitors tended to view artworks from further away. No significant main effects appeared for the other personality factors (neuroticism: *b* = .01 [-.25, .28], *SE* = .14, *p* = .932; agreeableness: *b* = -.01 [-.22, .19], *SE* = .10, *p* = .907; conscientiousness: *b* = .06 [-.15, .28], *SE* = .11, *p* = .581). Likewise, aesthetic fluency (*b* = .04 [-.16, .23], *SE* = .10, *p* = .707) and aesthetic responsiveness (*b* = -.07 [-.25, .11], *SE* = .09, *p* = .449) did not have main effects on viewing distance.

Next, for the within-person main effects, artwork area showed a main effect that replicated past work in lab and gallery contexts (*b* = .41 [.38, .44], *SE* = .02, *p* < .001): people stood farther away from larger artworks and closer to smaller ones. No within-person main effect appeared for artwork abstraction (*b* = .10 [-.05, .24], *SE* = .07, *p* = .181), so people didn't tend to stand closer or farther for abstract or representational works.

Finally, for cross-level interactions with artwork size, openness to experience marginally moderated the effect of artwork size on viewing distance (*b* = -.04 [-.08, .00], *SE* = .02, *p* = .070): as openness to experience increased, the effect of artwork size weakened, so highly open people were less affected by size. No other personality traits or art-related variables had a significant interaction effect (neuroticism: *b* = -.02 [-.07, .04], *SE* = .03, *p* = .539; extraversion: *b* = .03 [-.01, .08], *SE* = .02, *p* = .128; agreeableness: *b* = .00 [-.04, .04], *SE* = .02, *p* = .887; conscientiousness: *b* = -.01 [-.05 .04], *SE* = .02, *p* = .779; aesthetic fluency: *b* = -.02 [-.05, .02], *SE* = .02, *p* = .408; aesthetic responsiveness: *b* = -.02 [-.05, .02], *SE* = .02, *p* = .270).

For interactions with abstraction, only extraversion moderated the effect of abstraction on viewing distance (*b* = .18 [.00, .37], *SE* = .09, *p* = .050): introverted people were more likely to choose a closer viewing distance to representational works. No other moderating effects appeared (neuroticism: *b* = .16 [-.06, .38], *SE* = .11, *p* = .142; openness: *b* = -.06 [-.22, .09], *SE* = .08, *p* = .420; agreeableness: *b* = -.04 [-.16, .09], *SE* = .06, *p* = .559; conscientiousness: *b* = .07 [-.10, .25], *SE* = .09, *p* = .421); aesthetic fluency: *b* = -.09 [-.25, .07], *SE* = .08, *p* = .264; aesthetic responsiveness: *b* = .01 [-.14, .17], *SE* = .08, *p* = .861).

Discussion

Increases in access to technology, concerns about public health and safety, and a general zeitgeist of cultural sharing have allowed the use of digital tools to proliferate in cultural institutions. Inclusion of virtual gallery tools by art museums likely represents an effort to broaden visitor bases and take advantage of innovative and unique digital engagement tools. Despite increases in these aims, however, the psychology behind visits to virtual art galleries is not well understood. It is possible that individual differences such as personality underly differences in visit behaviors during visits to digital spaces. Previous studies conducted in physical museum environments have been limited in their capacity to address these questions due to the time burden placed on natural museumgoers by these types of measures.

The present research used a new virtual gallery tool to expand on previous museum studies of the psychology of art in two important ways. First, it further validated OGAR as a viable tool for research into interactions with art; second, it explored the roles of personality and other individual differences in the behavior of virtual visitors. This study administered a battery of personality and individual difference questionnaires to a diverse online sample of adult users, followed by an unstructured virtual gallery visit. The gallery used featured three rooms—each accessible by the other two—with a total of 24 artworks hung in the space. Artworks were half representational and half abstract, spanning a range of genres, styles, art historical periods, and sizes. The project's main goals were to observe how the Big Five personality traits and art-related individual differences (aesthetic fluency and aesthetic responsiveness) affected overall gallery behaviors (e.g., visit time and distance traveled) and how artwork qualities (e.g., artwork size and abstraction) affected the viewing behavior.

The overall gallery behaviors in the OGAR virtual gallery appeared realistic and coherent, as in our pilot work (Rodriguez-Boerwinkle et al., 2023b). The participants actively used the gallery to approach and view artworks, as evidenced by hot-spots in front of each artwork on the gallery heatmap, and they viewed larger artworks from further away (Estrada-Gonzalez et al., 2020). At the same time, broad variability appeared in how people visited the gallery, including variability between people (e.g., visit time and distance traveled) and within people (e.g., viewing time and distance). This variability naturally invited exploring predictors that can illuminate people's behaviors within the virtual gallery space.

Personality as a Predictor of Visit Behavior

How did personality traits and other individual differences influence virtual visit behaviors? Openness to experience, a major factor in the psychology of art and aesthetics (Feist

& Brady, 2004; Kaufman et al., 2016; Silvia et al., 2015), was associated with most of the outcomes examined in the current study. People high in openness to experience spent longer and traveled further in the virtual gallery. Higher openness to experience also predicted greater proportion of time spent viewing the artwork, so even controlling for increased visit time, highly open individuals spent more of their visit looking at art. These results lend support to the idea that highly open people are more likely to experience immersion in mediated environments—environments where content or environmental stimuli are created and then experienced, such as in museums, art galleries, or institutions or when people read books, watch movies, or play videogames (Weibel et al., 2010). Immersion in virtual gallery environments like OGAR, in turn, predicts a range of greater well-being measures following virtual art gallery visits (Cotter et al., 2023a).

Openness to experience predicted some more fine-grained behaviors as well. Visitors high in openness to experience viewed individual artworks for longer and from a closer average distance. While openness to experience has been found to predict greater viewing times for isolated art images before in lab settings (Fayn et al., 2015), this is the first study to demonstrate this effect in the context of a virtual gallery space. In addition, openness to experience moderated some of the effects of artwork features. For highly open people, the effects of artwork size and abstraction on viewing time were stronger, so the viewing behavior of open people was more strongly affected by these artwork features. Overall, these findings expand the idea that openness to experience—the cornerstone trait in the psychology of aesthetics and the arts (Swami & Furnham, 2014)—predicts how people experience visual art in virtual museum contexts.

After openness to experience, extraversion was the trait most consistently linked to virtual gallery behavior. These results are more intuitive when framed through the lens of low extraversion, or introversion. The relatively introverted participants spent longer in the gallery, traveled further in the gallery, and spent more time viewing individual artworks. Introverted participants were also more sensitive to the effect of image area on their viewing times. All told, introversion was widely related to greater engagement with the virtual gallery, but the reasons for this remain unclear. Some research has found that high extraversion and sensation seeking predict a preference for visual art that is more energetic and complex (Swami & Furnham, 2014; Twomey et al., 1998). More broadly, museums are quiet, solitary places, and people tend to interact with works of art alone, even if they visit as a group (Smith, 2014).

A different interpretation of these results suggests the importance of further investigating virtual gallery experiences as distinct forms of art engagement in and of themselves. Detached from aesthetics, another possibility is that introverted individuals are simply more comfortable in the virtual gallery. A large literature links internet use with introversion, including the ability to engage with one's interests and express one's true self through computer-based interactions (Amichai-Hamburger et al., 2002; Ebling-Witte et al., 2007). If introverted visitors are more comfortable in the online gallery due to their computer habits, then they may be more likely to engage with the experience, suggesting potentially distinct underlying differences in who chooses to visit virtual art galleries over real ones. Indeed, differences related to comfort with technology may also be at play in virtual gallery experiences in addition to introversion. Although OGAR has been rated highly on technological usability in prior work (i.e., Rodriguez-Boerwinkle et al., 2023b), more research is needed to determine the relationship between comfort with technology and positive outcomes related to virtual gallery visits.

A few additional effects appeared for other variables. Visitors higher in neuroticism, for example, spent less time in the gallery; participants higher in agreeableness both visited for longer and traveled a greater distance in the virtual gallery. This latter effect may reflect the study requests made of paid participants, as more agreeable people are more likely to be overrepresented in demanding studies (Zhou & Fishbach, 2016). Finally, aesthetic fluency predicted visit time as well, which indicates that people high in art knowledge were more engaged with the gallery. Conversely, essentially no relationships appeared for conscientiousness or for aesthetic responsiveness. Conscientiousness is not a major variable in aesthetics research, but the lack of effects for aesthetic responsiveness, measured with the AREA (Schlotz et al., 2020), is more notable. Not much is known about this relatively new scale, so we encourage researchers to include it in future studies to expand the relatively small knowledge base about how the scale behaves in real and virtual environments.

Artwork Characteristics as Predictors of Viewing Behavior

Viewing behavior in the virtual gallery was sensitive to some of the factors that affect viewing behavior in real-world spaces. Notably, our participants engaged with larger works for longer and viewed them from further away on average. This replicates past work on image area (Estrada-Gonzalez et al., 2020) and suggests that virtual environments could be a good option for researchers interested in studying viewing distance. The virtual gallery can balance realism with precision and control, affording manipulations of image types, features, and sizes that can't practically be varied in real-world spaces and thus allowing the testing of some new questions about image size and its effects (e.g., Seidel & Prince, 2018).

We also found that representational art was normally viewed for longer than abstract art. This finding, combined with the observation that art viewing measurements tracked by human judges tend to be longer on average than those tracked by eye trackers or other similar technologies like OGAR, may explain why viewing times are on the shorter side in the current study. Most of the literature on art viewing from art museums has used artworks that are all representational (e.g., Reitstätter et al., 2020; Smith & Smith, 2001; Smith et al., 2017). Since visitors in this virtual gallery tended to view representational works for longer than abstract works, and the artworks used here are half abstract, shorter average viewing times may be expected. More research is needed, of course, to see if this effect is present in in-person environments, but the current findings are encouraging.

Conclusion

The present research illustrated how people behaved during a visit to a virtual art gallery and explored how personality traits and individual differences predicted a wide range of visit behaviors. The findings show how virtual gallery tools can be used to answer psychological questions about museum visitors, both for basic researchers looking for a practical, modifiable model for studying real-world behaviors and for art professionals who wish to study virtual visitors in their own right as they seek to bolster engagement with virtual museum content—a rapidly growing goal of cultural institutions across the world (Agostino, 2020).

CHAPTER IV: MAPPING VISIT BEHAVIORS IN A VIRTUAL ART GALLERY TO VISITOR ENGAGEMENT PROFILES USING LATENT CLASS ANALYSIS

"I'm convinced that art and technology go together," noted the artist David Hockney, "and always have, for centuries" (Govan, 2013). In our century, an important intersection of art and technology has been the efforts by museums to create virtual versions of their galleries that can extend the reach of their collections beyond their physical walls. As art museums and gallery spaces expand their audience by building their virtual presence, there's a growing need to understand the psychology of visits to virtual museums (International Council of Museums, 2023; Rodriguez-Boerwinkle & Silvia, 2023a). The psychology of art and the field of visitor studies have a long-standing interest in understanding the psychology of museum visitors, such as who visits a museum, how they navigate the space and engage with the works on display, and how they experience, think about, and remember their visit (Bitgood, 2006; Cotter et al., 2022a; Leder & Nadal, 2014; Smith & Smith, 2001). While there are surely parallels between visits to physical and virtual museums, virtual visits raise many unique issues and are a worthy topic of study in their own right.

In the present research, we examined the psychology of virtual art visits. Drawing from the literature on visitors in real-world gallery spaces and using an open-source virtual gallery tool (Rodriguez-Boerwinkle et al., 2023b), we sought to characterize what virtual gallery visits look like, with an emphasis on how visitors navigated the gallery rooms and engaged with the works on display. After illustrating typical virtual visits, we used latent class analysis to classify virtual visitors into types based on their patterns of gallery behaviors and to explore if the types differed in important individual differences related to the arts, such as art knowledge and openness to experience. Altogether, this work demonstrates the potential of virtual gallery tools for research in the psychology of art and enhances our understanding of virtual art engagement.

Understanding Behaviors in Art Museums

To get a foothold into understanding how virtual visitors engage with virtual art spaces, a natural place to start is the extensive literature on the psychology of museum visits. Research in the psychology of art and visitor studies has identified many variables that are useful for characterizing how people engage with real-world museum and gallery spaces (Clarke et al., 1984; Linden & Wagemans, 2021; Smith & Smith, 2001), so this literature is a fertile starting point for characterizing virtual visits. For the purposes of the present research, which emphasizes how people navigate the gallery space and engage with its artworks, several groups of visit variables are particularly relevant.

Global Visit Measures

The first group of variables are general, global measures of visit behavior, such as the duration of a gallery visit (*gallery time*) and how much distance people covered in the gallery (*gallery distance*). These variables have been widely studied, in part because of their obvious practical importance to museum professionals. Research finds wide variability in how long people spend during a visit and how much of a museum space they traverse (Bitgood & Dukes, 2006; Rodriguez-Boerwinkle & Silvia, 2023c). These factors of the gallery visit are influenced by individual differences in the observer as well as design or architectural features of the space. It's worth emphasizing that when it comes to understanding a visitor's motivation and aesthetic experience, more gallery time and distance are not necessarily better (Brieber et al., 2020): many visitors will choose to focus on a particularly appealing or meaningful part of the space.

Art Viewing and Visiting

The second category of variables involves art viewing, which is the most highly studied marker of art engagement (Brieber et al., 2014; Reitstätter et al., 2020; Smith & Smith, 2001). Art viewing is driven by many factors, such as curatorial factors (e.g., didactic text accompanying the work; Lin & Yao, 2018; Tröndle et al., 2014a), social and environmental factors (e.g., the presence of others near the work and the lighting design; Chang, 2006), and individual differences in the viewers' interests and background (Pihko et al., 2011).

Art viewing is a broad category of visitor behavior that includes many kinds of viewing activity, such as glancing at an artwork from the doorway of an exhibit room, skimming artworks while meandering through a gallery, and stopping in front of a work to view it for an extended time. Instances where visitors stop and focus on a work are particularly interesting, and we'll refer to this subtype of art viewing as "art visits." According to the "stopping for knowledge" hypothesis, motor inhibition is a key part of the aesthetic process (Sarasso et al., 2020). Pausing during aesthetic engagement may increase aesthetic pleasure and optimize learning and memory for objects—cognitive outcomes that cannot be achieved with glancing alone. In studies of visitor engagement and exhibit evaluation, stopping behavior is regarded as an important indicator of exhibit success (e.g., Bailey et al., 1998; Bitgood, 2006). Indeed, stopping is often a prerequisite for choosing to engage in other activities such as reading labels, listening to audio guides, or even taking selfies.

For works that visitors choose to view, whether it is glancing or stopping, *viewing time* is one of the major variables studied in art viewing. For example, Smith and Smith (2001), in a study of visitors to the Metropolitan Museum of Art, recorded seconds spent viewing an artwork (timed with a stopwatch) as a major output in their work (see also Smith & Smith, 2001; Smith, et al., 2017). Other work has also examined viewing time with eye-tracking methods (Garbutt et al., 2020; Palumbo et al., 2023; Reitstätter et al., 2020). In general, the literature suggests that art viewing time is fairly short (often less than 30 seconds), with most people viewing a single artwork for less time and only a few gazing at it for much longer.

Another key parameter for art viewing is *viewing distance*: how near or far from an artwork people stand when viewing it, such as moving close to peer at fine details and brushwork to stepping back to take in the work as a whole. The small literature on viewing distance finds that visitors are strongly affected by the size of the artwork, expressed as its area: people stand closer to smaller works and farther from larger ones (Clarke et al., 1984; Carbon, 2017; Estrada-Gonzalez et al., 2020).

Movement and Navigation

The third category of variables involves visitors' navigation and movement in the gallery space. In the field of visitor studies, visitor flow through exhibits and gallery spaces represents a key aspect of the visit experience. For example, Bitgood (2006) proposed that visitors follow a general value principle, whereby as they navigate through exhibit spaces, they evaluate the benefits and costs of their engagement behaviors, leading to behaviors that represent low levels of engagement for most artwork interactions and more effortful levels of engagement behaviors with a few artworks that are judged as "worth it" (Bitgood, 2006). This framework can illuminate many visitor behaviors observed in museum environments, such as "hello" glances around the room, pauses upon entering a gallery, and other orienting behaviors as visitors enter the space (Bitgood, 2006; Tröndle et al., 2014b); the tendency for visitors to briefly pass by every artwork in sequence (Bitgood, 2006; Tröndle et al., 2014b); and decisions that visitors make about when to leave or exit the gallery (Bitgood & Dukes, 2006).

While movement descriptors can be as simple as asking what rooms visitors entered, more informative movement descriptors have to do with describing continuous visitor movement through a gallery space or the shape of the path itself. For example, directional bias—the tendency to have more leftward or rightward movement—has often been mentioned by the visitor engagement literature. Visitor studies researchers have commented on the observation that most people "go right" in the exhibit space (Bitgood, 2006; Garbutt et al. 2020). As Whyte (1988) somewhat provocatively suggested: "oddballs…go left" when they navigate a public space (p. 57). However, this movement quirk has not been systematically or empirically studied. Trajectory sinuosity—the straightness vs curvature of the navigational path taken through a gallery—has roots in animal studies but has found recent use in museum research (i.e., Kühnapfel et al., 2024; Rodriguez-Boerwinkle et al., 2023b). In ecological settings, trajectories with high sinuosity (or low straightness) often indicate meandering, undirected search paths, while straighter paths are more informed or goal oriented (McLean & Volponi, 2018). In gallery settings, the straightness of one's path around an artwork has been used to characterize overall movement-based engagement with artwork (Kühnapfel et al., 2024), but has not been linked to other predictors of engagement such as personality or art knowledge.

Efforts to Classify Museum Visitors

Because museum visits are incredibly complex psychological events and because people vary so widely in their visits, researchers have turned to classification methods to distill aspects of museum visits into a smaller number of distinct, nominal types. For example, Falk's (2006, 2008) influential taxonomy proposed that visitors had distinct kinds of identity-related motives, such as "explorers" guided by curiosity and "facilitators" motivated by social goals (Cotter et al., 2022a). Linden and Wagemans (2021) built a taxonomy of museum navigation behavior aimed at classifying art viewing behaviors captured by mobile eye tracking devices. In this proposed taxonomy, multiple simple behaviors such as turning, strolling, and centering are components of hierarchically more complex behaviors, such as changing perspective.

Other work has aimed to classify aspects of the visitor's aesthetic and emotional experience. Cotter et al. (2024) used latent class analysis to categorize global patterns of experienced emotions across five domains of psychological flourishing during art museum visits. They found that visitors' emotional experiences could be characterized by three latent classes: visitors with (1) elevated positive emotions, (2) elevated negative emotions, and (3) highly negative emotions. Notably, visitors in the elevated positive emotion class experienced greater psychological flourishing than the other two classes.

Another line of work has explored the classification of movement behaviors in gallery spaces. Kühnapfel and colleagues (2024) employed a principal components analysis (PCA) in a data-driven approach to examine the "*shared* ways we engage as embodied beings with an artwork" (p. 4). Their examination of movement trajectories for 39 participants around a single artwork revealed four distinct clusters that varied according to their visit length, navigational path length, position, and straightness among other movement related variables.

Overall, classification approaches to visitor behaviors and experiences can distill a wide range of visit features into a more tractable set of patterns. These approaches find their use the design of informed and customized (often technological) experiences (Eardley et al., 2016; Sundar et al., 2015). In the present work, we used latent class analysis to identify distinct patterns, if any, of how virtual visitors navigated the space and engaged with the artworks.

Prior Research on Virtual Visitors

The literature on experiences in virtual art galleries is a relatively new one. Following notable increases in the use of these tools by art museums and galleries (Agostino, 2020), psychology of art researchers have taken up these tools to explore a wide variety of topics, ranging from basic questions of art viewing (Rodriguez-Boerwinkle & Silvia, 2023c) to interventions designed to promote well-being (Cotter et al., 2022b, Cotter et al., 2023a). As a class of research tools, virtual galleries offer several unique advantages over traditional field studies. For example, whereas in-person data collection is limited in scope, manipulability, and precision, virtual environments can be designed to flexibly meet the needs of researchers, since they are wholly computed spaces (Rodriguez-Boerwinkle & Silvia, 2023a). Much of the new work being conducted using virtual gallery tools traces to an open-source tool, named the Open Gallery for Arts Research (OGAR), described by Rodriguez-Boerwinkle et al. (2023b). OGAR was designed specifically to meet the needs of researchers interested in art and aesthetics, including robust manipulability and behavioral data capture capabilities, integration with commonly used survey collection platforms, and low resource requirements for successful implementation on the sides of both the gallery designer and the virtual visitor.

Subsequent research using OGAR has revealed that visits to virtual art galleries might have distinct benefits to psychological flourishing. In one study by Cotter et al. (2022b), it was found people felt more immersed in a repeated engagement (of 5 weekly sessions) with art viewed in a virtual gallery than during a series of control sessions that instructed participants to complete readings related to topics from art history. Immersion was subsequently found to predict changes in overall engagement, meaning, and autonomy satisfaction over the course of 4 weeks of participation in the intervention. In another study, repeated visits to an OGAR-based virtual gallery were associated with greater post-visit well-being and a more positive emotional state (Cotter et al., 2023a). Together, these studies suggest that virtual art engagement may hold similar well-being benefits to in-person art engagement.

OGAR has also been used to explore individual and art-level predictors of art engagement. Using an unconstrained visit paradigm, whereby participants were instructed to visit a virtual gallery for as long as they wished, freely viewing artworks during the visit, Rodriguez-Boerwinkle and Silvia (2023c) found several personality-based predictors of how people engaged with artwork in the virtual gallery. Namely, this work revealed that openness to experience (a common predictor of art engagement used throughout the art and aesthetics literature) had widespread effects on several virtual visit behaviors, correlating with longer visit times, greater travel distances, a greater proportion of time spent viewing artwork, and a longer overall time spent looking at art. Extraversion, meanwhile, was related to decreased engagement, such as shorter a visit time and distance traveled within the gallery and shorter viewing times for individual artworks on average. Artwork characteristics, such as its size or whether its content was representational also impacted viewing behavior: larger images were viewed longer and from further away on average and representational art was typically viewed for longer than abstract art. All told, this study provided insight into how individual differences and basic artwork qualities can predict a range of visit behaviors.

So far, the literature on psychological and behavioral aspects of virtual gallery engagement has focused on viewing behavior as both an important predictor and outcome of the visit experience. Largely, this initial work has been seen as a compliment to traditional in-person findings about art engagement; however, these types of digital experiences may, in many ways, represent a psychologically distinct form of art engagement, drawing its own type of digital visitor with unique interaction affordances and goals, that is not fully understood. Several gaps still exist in this knowledge set. One notable gap involves our understanding of navigation and movement in the digital space—what does art viewing look like in the virtual gallery? Another low-hanging fruit for better understanding virtual gallery experiences lies in our ability to capture complex and even compound behaviors and asking ourselves—how can complex behavioral experiences be organized in meaningful ways? Focusing on digital navigation and movement in virtual gallery spaces enhances our understanding of digital art engagement, similar to the descriptions of in-person engagement offered by Kühnapfel et al. (2024). Further, exploring methods for categorizing and classifying behavioral aspects of the virtual gallery experience extends our understanding of complex interactions between the art, the viewer, and the environment while demonstrating the potential of virtual tools to capture and use the rich data inherent in digital experiences.

The Present Study

The present research sought to illuminate visitor behavior during unconstrained visits to a virtual art gallery. Our work was guided by three main questions: (1) What does a virtual gallery visit look like? (2) Can virtual visitors be classified according to their gallery behaviors? And (3) how do these types of visitors differ?

Our first research question was addressed by recruiting an online sample to engage in an unconstrained virtual art gallery visit created with OGAR, an open-source research tool (Rodriguez-Boerwinkle et al., 2023b). By allowing visitors to move freely in the space, without any specific objectives or constraints, virtual gallery visits in this study resemble typical real-life scenarios in galleries. Additionally, the architecture of the space was designed to minimize potential influence over navigational trajectory—an important consideration for studying movement patterns in situ. This question was ultimately discussed in terms of descriptive results broadly concerning global visit variables, art viewing and visiting variables, and navigation and movement variables.

After describing the visit characteristics of our sample, we moved to address our second question—can we group people based on quantified behaviors—by using nine of our described variables as indicators for a latent class analysis. Latent class analysis is a model-based statistical method for grouping elements into classes based on similar patterns on indicator variables (Collins & Lanza, 2010). In this case, it was used to group participants based on shared patterns of behavior quantified within the gallery.

Finally, our last question—how visitor types differ based on individual differences—was addressed using measures of demographic variables, personality traits, and art-specific individual-differences collected before the virtual gallery visits. These measures allowed us to explore how the different "types" of virtual visitors differed, thus giving insight into the meaning of the different latent classes.

Methods

Participants

This project was approved by the University of North Carolina at Greensboro (UNCG) IRB (#21-0311). A sample of 320 adult online participants were recruited from the Prolific.co survey panel. To be eligible for participation, participants were required to be native English speakers residing in predominantly English-speaking countries (Australia, Canada, Ireland, New Zealand, UK, USA) between the ages of 18 and 70 with a minimum study approval rate of 95%. All participants provided informed consent and were paid USD $3 for their participation in a broader study of personality and virtual art visits (Rodriguez-Boerwinkle & Silvia, 2023c).

After data collection was complete, participants were screened for careless responding on self-report scales and drop out from poor browser performance (indicated by static avatars) or a failure to visit at least two of three rooms. To ensure that participation would be compatible with the virtual gallery, devices were restricted to desktop or laptop computers only via Prolific's recruitment settings. After the recruitment goal was reached, participants were screened for technological considerations relevant to gallery performance quality. These exclusion checks included minimum measures of OGAR system performance, browser failures, and other unexpected events and are described in greater detail in the online supplemental material. Behavioral and technological exclusions yielded a final sample size of 264 people (age *M* = 33.85 years, *SD* = 12.30, range from 18 to 69; female-identifying: 41.3%).

Procedure

The present study was conducted in Qualtrics using an embeddable virtual gallery instance. First, participants completed a series of demographic questions regarding age, country of residence, and gender, and individual difference assessments of personality and subjective art knowledge. Then they were directed to a survey screen containing a virtual gallery that could be entered by clicking on it. The page also contained directions on how to interact in the gallery. No training for gallery use was implemented, based on the good system usability reports from similar procedures used in Rodriguez-Boerwinkle et al. (2023b). Once participants clicked on the gallery, they entered full screen mode and were instructed to visit the space for as long as they wished, using their keyboard and mouse to navigate and direct their view. After finishing their visit and exiting the gallery, participants concluded their participation by answering a few post-visit questions about their experience.

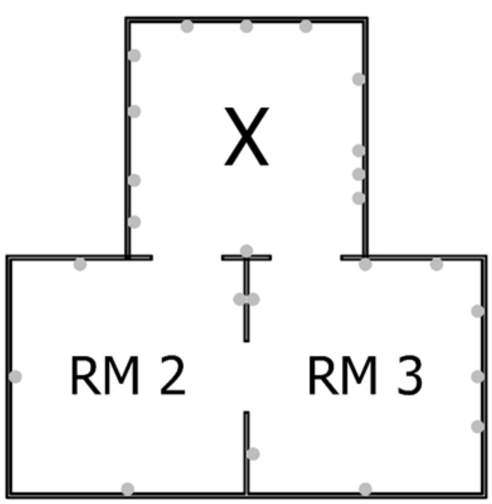
Study Resources

To design and implement a browser-compatible virtual gallery that participants could interact with on their personal hardware, we used OGAR (Rodriguez-Boerwinkle et al., 2023b). This tool allows researchers to design virtual galleries based on their research needs and results in a gallery that is presented as a 3D space with a first-person viewing perspective. Throughout a participant's gallery visit, participants navigate the gallery with naturalistic and continuous "smooth" movement and data regarding their in-gallery behaviors is recorded for the researcher to use in subsequent analyses.

Gallery Definition

An OGAR gallery definition describes the specifications of the virtual space, artworks, and avatar characteristics. It includes information such as architectural layout of the space, colors used for the floor, ceiling or walls, artwork locations and sizes, participant avatar starting location, eye height, and more. The current study used a three-room gallery that featured interconnected rooms from which visitors could pass into any room from any other room. Each room was square, measuring 10 m × 10 m with a total gallery floor area of 300 m^2. Artworks were displayed in their "true size" in the gallery. Their locations, as well as the rest of the gallery floorplan, can be seen in Figure 4.1.

Figure 4.1. Gallery Floorplan



Note. The starting location, in Room 1 of the gallery, is indicated by the “X”. Participants were oriented directly south at the starting location. Room regions 2 and 3 are labeled as “RM 2” and “RM 3”, respectively. Artwork locations are indicated with gray dots, slightly offset from the walls for better visibility.

Artworks

Artworks were chosen from the Vienna Art Pictures System (VAPS), which is a comprehensive dataset of 999 art images from the western art tradition that have been gathered for use in empirical aesthetics research (Fekete et al., 2022). The 24 artworks selected for this study were evenly split between representational and abstract works, and covered a wide range of art historical periods, genres, styles, content, and sizes. Artworks types were evenly spread throughout the gallery and curated in a manner consistent with curatorial design principles outlined in *The Curator’s Handbook*, a common pocket guide for industry professionals (George, 2015). The resolution of each artwork was considered to meet the viewing demands of the virtual gallery. For a complete list of artworks used in this study, see Table A2.

Measures of Individual Differences

Participants reported personal demographics, including age (in years), gender, and country of residence at the start of their survey. Gender responses were coded as binary (female = 1, male = 0, other responses = missing). Browser specifications were also collected via a hidden meta information question in Qualtrics. Browser information, however, was not used in analyses and was collected for debugging purposes, if necessary. After their visit, participants were asked “Did you feel motion sick, dizzy, or nauseous from the virtual gallery?” with a scale from one (*No, not at all*) to seven (*Yes, very strongly*). Although rare, nausea can be related to lower user experience in virtual galleries and may additionally indicate low data quality or gallery performance issues (Rodriguez-Boerwinkle et al., 2023b).

Personality and Art Knowledge

Before visiting the gallery, personality traits were assessed using the 60-item NEO-3 Five Factor Inventory (McCrae & Costa, 2007). This inventory measures neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness with a 5-point scale (1 = *strongly disagree,* 5 = *strongly agree*). Reliability for each of the five NEO factors was good: $\alpha = .92$ (N), $\alpha = .85$ (E), $\alpha = .79$ (O), $\alpha = .75$ (A), and $\alpha = .89$ (C), respectively.

To measure art knowledge, we used a revised version of the Aesthetic Fluency Scale. The original scale, introduced by Smith and Smith (2006), asks participants how familiar they are with 10 art-related concepts. The current study, however, uses a recently updated version of the Aesthetic Fluency Scale, which includes a wider scope than the original survey and a simplified response format (Cotter et al., 2023c). The updated 36-item scale, with response options ranging from 0 (*I don't really know anything about this artist or term*) to 2 (*I know a lot about this artist or item*), showed a test reliability of $\alpha = .95$.

Measures of Virtual Gallery Behavior

Every 200 ms throughout a participant's gallery visit, OGAR collects and records the participant's position (defined by X and Y coordinates within the gallery floorspace) and gaze (in terms of pitch and yaw, defined in terms of radians) as well as the movement speed (in m/s). These simple measurements, along with details about the gallery set-up obtained from its gallery definition, can be used to reconstruct the visit experience, and operationalize important behavioral constructs of gallery engagement.

Global Visit Measures

Global visit measures describe the overall exposure of participants to the gallery and consider the gallery visit as a broader level of analysis (Smith, 2014).

Gallery Time. Gallery time, or the total time in seconds that a participant spent in the virtual gallery, was coded as the sum of 200 ms time points between entering and exiting the full screen mode of the gallery, accounting for if they did so multiple times.

Gallery Distance. Gallery distance, the length of the path participants took through the gallery, was calculated. Because the gallery floor space is represented in square meters, a single unit coordinate shift in X or Y represents a distance change of 1 meter within the gallery. The total distance traveled can thus be calculated using the distance formula, where the difference between subsequent positions can be summed for the total number of points in the path that a visitor took through the gallery.

Viewing and Art Visiting

If one imagines a ray extending from the pre-determined eye height of the participant's avatar in line with the gaze direction at a particular location in the gallery, then the intersection of that ray with any possible viewing target in the gallery (i.e., artworks, floor, ceiling, or walls) can be calculated. From this, a researcher can obtain what a participant is looking at, for how long, and from how far. This affords calculating more complex measures of viewing behavior, such as the number of artworks a person views, the average viewing time for any given artwork, and the proportion of time spent viewing artwork relative to other gallery features.

Number of Artworks Viewed. The number of viewed artworks represents the count of unique artworks viewed out of the total artworks available to view in the gallery. In this gallery, participants could view up to 24 artworks, but there were no constraints requiring visitors to view every artwork, so a person may choose not to view everything. Artwork views is the broadest measure of art viewing because even brief views while moving (see Linden & Wagemans, 2021) count as a view.

Number of Artworks Visited. As noted in the Introduction, some art viewing involves stopping in front of an artwork for an extended engagement with it (Linden & Wagemans, 2021; Smith, 2014), and that we refer to this subtype of art viewing as an “art visit.” Linden and Wagemans (2021) explain that complex behaviors, such as artwork visits, can be described in terms of the combination of hierarchically simpler behaviors such as approaching and gazing. Using the parameters afforded by OGAR, we specified the features that would define and quantify whether an instance of art viewing counted as a stopped “art visit”:

- The participant must be closer to the given artwork than any other artwork
- The participant must be currently viewing the given artwork
- The last viewed artwork must be different than the artwork being currently viewed (i.e., looking briefly at the wall next to the artwork does not constitute something different, but looking from one artwork to another does)
- The participant must be stopped for at least 1 second (functionally quantified as 900ms to account for possible lag in internet browser time keeping)

Using these criteria, we could count the number of artworks that people visited in this stopped-and-sustained sense of a visit. Keeping these parameters in mind, the number of initial artwork visits represents the count of artworks out of 24 possible artworks that participants viewed at least once.

Artwork Revisits. Since participants were free to view and to visit an artwork multiple times, artwork revisits were also calculated. This measure represents the total number of visits to artworks beyond an initial visit. For example, if an artwork was visited 5 times in total, its revisit count would be 4; an artwork visited only once would have 0 revisits. Revisits for each artwork were then summed for an individual to arrive at the total number of artwork revisits.

Art-viewing Ratio. Art viewing ratio, the proportion of total time spent in the gallery that was used to look at artworks as opposed to other features, allows artwork viewing time to be examined in a way that is not conflated with the total time that a person spends in the gallery. It is interpreted as a percentage.

Navigation and Movement

Navigation and movement variables represent important, yet under-studied, aspects of art engagement within the context of viewing spaces like galleries or museums.

Percentage of Time Stopped. Every time point that a participant's movement speed was recorded as zero was tagged as stopped. To calculate the percentage of the total time spent static, "stopped" time points were summed and divided against the total number of timepoints for each gallery visitor.

Navigational Direction. Two measurements of navigational direction were examined in the current study. First, we calculated the first room that a participant chose to enter from the starting location in room 1. The symmetrical nature of the gallery floorplan and the starting location that was equidistant from rooms 2 and 3 provided a navigational environment that was free from the biasing influences of architecture found in many real-life settings. Second, we calculated the total directional bias in participant path throughout the course of an entire visit. This was achieved by representing artworks in terms of ordered lists and keeping a running tally of whether the participant was "moving to the left" or "moving to the right" each time the closest artwork changed. Once the navigation path is complete, the resulting measure of directional bias can be interpreted thusly: negative values represent leftward bias, with more strongly negative values indicating more pronounced bias in that direction; zero represents no bias in the total navigational path; and positive values represent a bias towards rightward movement, with more strongly positive values indicating more pronounced bias in that direction.

Sinuosity. In the current study, sinuosity (S) is used to describe the level of “wandering” in the navigational path of a participant through the virtual gallery. This measure, calculated using the *trajr* package in R (McLean & Volponi, 2018), represents the tortuosity or curvature of a path, ranging from a straight-line movement (S = 0) to random wandering (S > 4 radians; Benhamou, 2004). Navigational deviation from a straight line, or S, is measured in radians/meter$^{.5}$.

Results

Analysis Approach

The data and analysis files are available at Open Science Framework (https://osf.io/6mqt4/). The data were screened and cleaned in R 4.3 (R Core Team, 2023). Table 4.1 shows descriptive statistics for all outcomes. Pearson’s *r*, which is interpretable as small (.10), medium (.30), or large (.50) effects (Cumming, 2012), was used to describe correlational effect sizes.

Table 4.1. Descriptive Statistics for All Outcomes

Variable	***M (SD)***	***Median***	***Min/Max***
Age	33.85 (12.30)	32	18, 69
Gallery Time	3.91 (3.00)	3.05	.17, 18.97
Gallery Distance	118.83 (55.50)	114.92	9.95, 412.38

Artworks Viewed	18.84 (5.74)	21	3, 24
Art Viewing Ratio	0.51 (0.19)	0.51	0.03, 0.91
Initial Artwork Visits	12.18 (6.70)	12	0, 24
Artworks Revisited	1.15 (1.97)	0	0, 17
% Time Stopped	.54 (.16)	.54	.09, .93
Directional Bias	2.04 (11.43)	2	-24, 22
Sinuosity	1.45 (.26)	1.46	.43, 2.13
Nausea	1.49 (1.10)	1	1, 7
NEO Agreeableness	3.63 (0.50)	3.67	2.17, 4.75
NEO Conscientiousness	3.38 (0.69)	3.33	1.25, 5.00
NEO Extraversion	2.88 (0.62)	2.92	1.17, 4.92
NEO Neuroticism	3.34 (0.82)	3.42	1.08, 4.92
NEO Openness	3.89 (0.51)	3.92	2.00, 4.92
Aesthetic Fluency	0.59 (0.36)	0.50	0, 1.83

Note. n = 264. The descriptive statistics are for the raw scores.

What Does a Virtual Gallery Visit Look Like?

Global Visit Behaviors

To get a broad sense of how gallery visits looked in our sample, we first explored overall gallery time and gallery distance traveled. On average, virtual gallery users toured the gallery for 3.91 (*SD* = 3.00) minutes and traveled about 118.83 (*SD* = 55.50) meters during their visit. Individual visit measures varied greatly, but time spent in the gallery and distance traveled were highly correlated ($r = .70$ [.63, .76], $p < .001$)—which makes sense when framed in terms of navigation in a real space (Rodriguez-Boerwinkle et al., 2023b).

Artwork Viewing

Art viewing was examined from two lenses: the number of artworks viewed, and art viewing ratio. Out of the 24 artworks present within the virtual gallery, visitors viewed around 19 artworks on average (*M* = 18.84; *SD* = 5.74; *Mdn* = 21), but most people viewed the entire set. Art viewing ratio—the proportion of the gallery time spent viewing art—was widely distributed, achieving a nearly uniform distribution, but on average people viewed artworks during about 51% (*SD* = .19) of their gallery time.

Artwork Visiting and Revisiting

Because the participants were free to disregard any artworks they wished or to return to them as many times as they wished, artwork visits—the subset of art viewing that involves stopped, intensive viewing of a work—was explored with both initial visits (how many of the 24 works were viewed in this stopped, extended manner) and with revisits (how many of the 24 works were visited again). Participants had initial artwork visits of about 12 artworks out of 24 on average (*M* = 12.18; *SD* = 6.70; *Mdn* = 12), but many people engaged with more. Reengaging with artwork was uncommon—virtual gallery users revisited only one artwork on average (*M* = 1.15; *SD* = 1.97; *Mdn* = 0)—but artwork revisit counts ranged from 0 to 17.

Navigation and Movement

Navigation and movement-related gallery behaviors were described in terms of percentage of time stopped, navigational direction, and sinuosity. Participants spent a little more than half the time they were in the gallery stopped (*M* = .54; *SD* = .16), with wide variation, including a cluster of participants that was mostly in motion and others who were mostly still.

When participants were moving, a few navigational trends emerged: more people chose to enter Room 3 (61.7%; to the left of the starting position) than Room 2 (39.0%; to the right of the starting position) when navigating out of the starting room. The average total navigational bias across the sample was slightly above zero, indicating slight rightward bias (*M* = 2.04) and dramatic variance (*SD* = 11.43) between participants. Finally, an examination of sinuosity revealed that navigational paths had an average sinuosity of 1.45 radians/meter$^{.5}$ (*SD* = .26), or about 83 degrees of average deviance from a straight-line path.

Can Virtual Visitors be Classified According to Their Gallery Behaviors?

We conducted latent class analyses to see if the participants could be classified into nominal "types" of virtual visits. To estimate possible classes, we used the following nine gallery indicators: number of initial artwork visits; number of artwork revisits; total gallery time; total gallery distance; number of artworks viewed; art-viewing ratio; percentage of time stopped; sinuosity; and directional bias. These indicators captured the major features of the gallery visit without being co-linear or redundant. The analyses were conducted using Mplus 8.1, using maximum likelihood with robust standard errors. The gallery indicators were first standardized as *z*-scores to place them on the same scale. Because latent class models can often fail to converge to the global minimum (Collins & Lanza, 2010), the models were estimated with 10,000 random starting values, and the 500 models that fit best after 25 initial iterations were then iterated to conclusion. The log-likelihood of the best-fitting latent class solution was then replicated with different random number seeds.

We tested class models ranging from 2 to 5 classes. For latent class analysis, an exploratory method, deciding on the number of classes involves both quantitative metrics as well as conceptual and substantive criteria (Collins & Lanza, 2010; Nylund et al., 2007). For the quantitative metrics (see Table 4.2), entropy—a marker of classification quality—was above .90 for the 3, 4, and 5 class models and highest for the 3-class model. The Akaike information criterion (AIC) and Bayesian information criterion (BIC) favored the five-class model. Bootstrapped likelihood ratio tests significantly favored the 5 classes over 4, and 4 classes over 3. On the substantive side, researchers should favor parsimony. Simpler class solutions are more likely to replicate in other samples, and very small classes (less than 5%) are likely to replicate only in very large samples. In addition, researchers should favor distinct, nominal classes over "intensity classes," which appear when two groups different quantitatively (i.e., they have a similar profile shape but a different level; Silvia et al., 2009). In our analyses, no class solution had a very small class, and in fact the smallest class (6.8% of the sample) was consistently identified across the 3, 4, and 5 class solutions.

Table 4.2. Model Statistics for the Latent Class Analyses

Number of Classes	AIC	BIC	Entropy	Smallest Class Size
Two	6215.909	6316.035	0.879	49.8%
Three	5888.85	6024.736	0.915	6.8%
Four	5755.539	5927.184	0.896	6.8%
Five	5659.243	5866.648	0.900	6.8%

We ultimately settled on the 4-class model as our final model because of its balance of parsimony and statistical metrics. Although the 5-class model had some better statistical metrics, the additional class was an intensity class with modest quantitative differences in level instead of a distinct nominal profile. Our labels and interpretations of the four classes were grounded in the latent profiles illustrated in Figure 4.2. Recall that the gallery behaviors are in the *z*-metric, so a score of 0 represents the full-sample average.

- One class—the Disengaged class (54 people, 20.5%)—was marked by consistently low engagement in the gallery. This group spent the shortest time in the gallery, traveled the least distance, and had by far the fewest works viewed and artworks visited.

- A second class—the Typical class (100 people, 37.9%)—represented a clump of participants who were a bit below average for most of the gallery behaviors. Their engagement with the gallery was relatively perfunctory, marked by an average gallery time, distance traveled, and number of artworks viewed and visited.
- Compared to the Disengaged and Typical groups, the Engaged class (92, 34.8%) was notably above average in most measures of gallery engagement. This group was marked by a relatively high number of initial artwork visits and works viewed, a higher proportion of time spent stopped and viewing art, and above average gallery time and distance traveled.
- Finally, the smallest group was a cluster of Revisitors (18, 6.8%)—a highly engaged group that was distinguished by the behavior of revisiting artworks. Compared to the other three groups, this small group was responsible for most of the revisits in the sample. Consistent with their repeated visits to the artworks, people in this group spent much longer in the gallery and traveled a greater distance within it.

Of the nine indicators, eight played a role in differentiating the four groups (see Figure 2), but directional bias (with higher number reflecting greater rightward bias) was reasonably similar for all four groups.

Figure 4.2. Latent Class Profiles for Virtual Gallery Behaviors

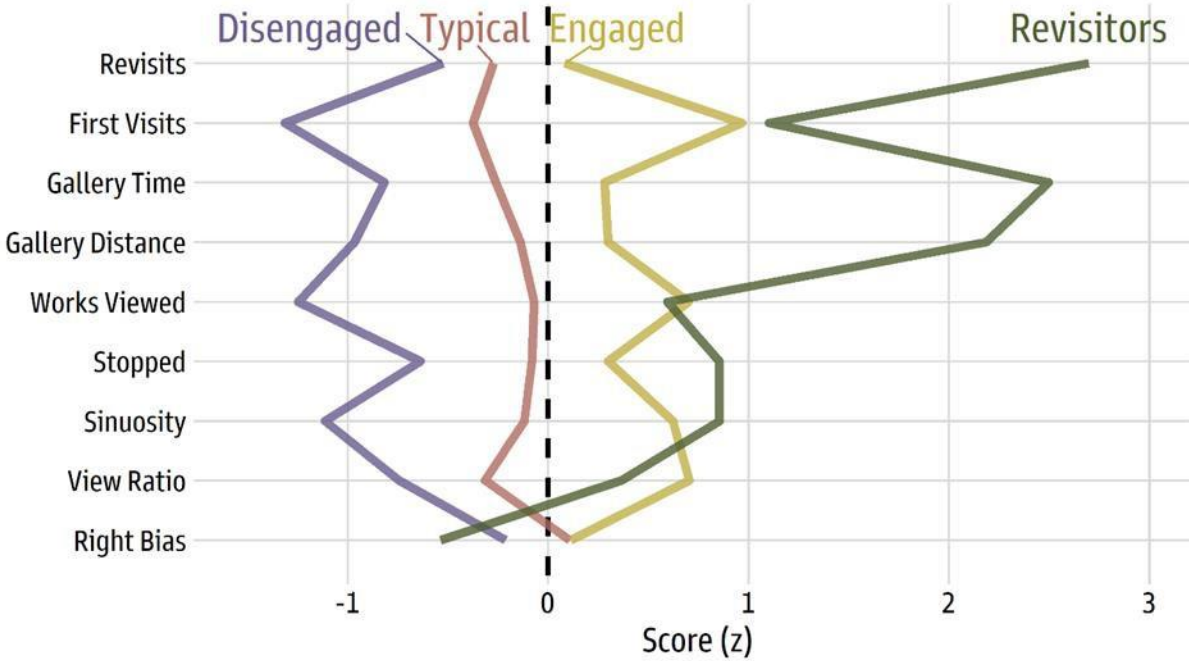
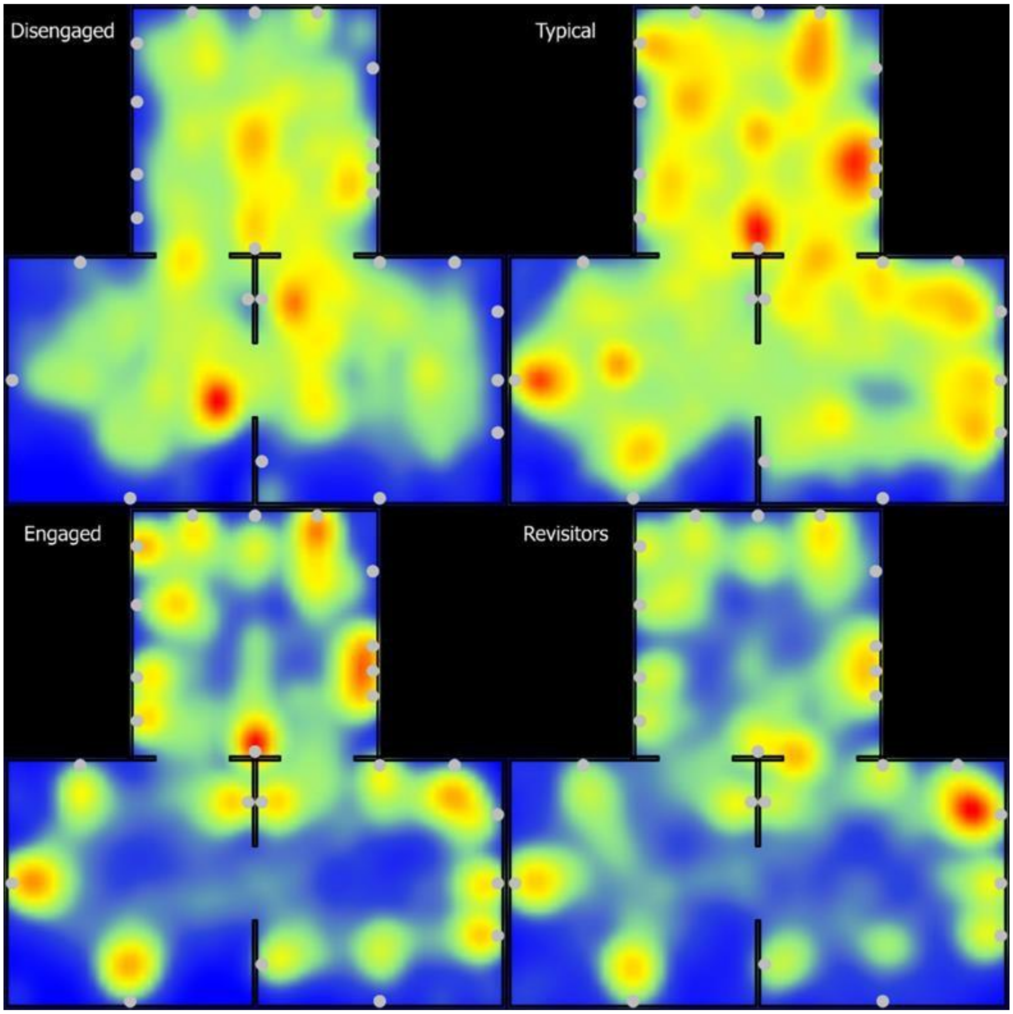


Figure 4.3 demonstrates differences in navigational heatmap densities for each class. Heatmaps were calculated using the X and Y timestamped position data, weighted equally for each participant in a given class. To prevent irrelevant heat spiking, starting positions for each group were omitted. Heatmap densities are scaled relative to the total movement of each group, as opposed to using a single scaling method across classes. This shows that the engaged and revisitor groups, for example, spent relatively more of their time in front of artworks than the typical and disengaged groups.

Figure 4.3. Movement Density Heatmaps for Each Class



Note. Participant data is grouped according to predicted class assignment. Movement data is weighted equally for each participant in a given class. To prevent irrelevant heat spiking, starting positions for each group were omitted. Heatmap densities are scaled relative to the total movement of each group, as opposed to using a single scaling method across classes.

How Do These Types of Visitors Differ?

To gain more insight into the latent classes, we explored if the classes differed in art knowledge, personality, and other individual differences. We used the BCH method (Bakk &

Vermunt, 2016) in Mplus, a model-based approach to estimating the means of the predictor variables that appropriately recognizes the probabilistic nature of each person's class membership. Significant differences between the four classes were found for several variables. The overall tests are shown in Table 4.3.

Table 4.3. Overall Tests of Significant Differences between the Four Latent Classes

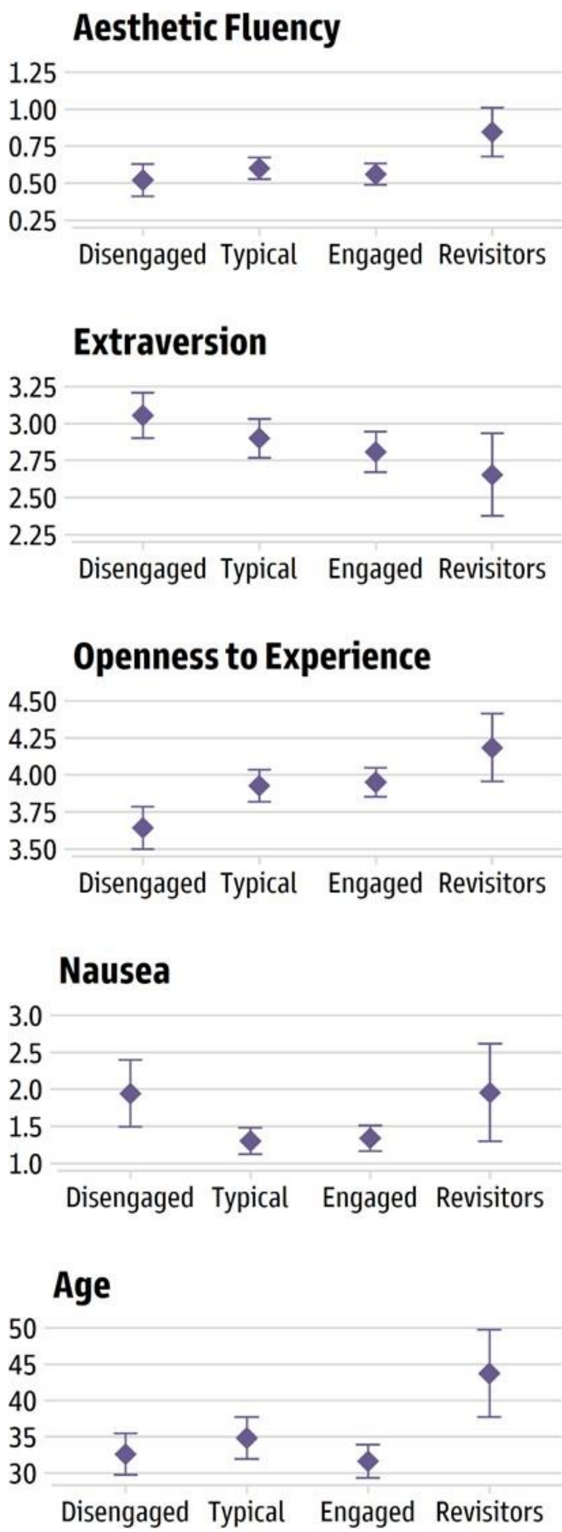
Predictor	Overall Test: $\chi^2(3\ df)$	*p*-value
Aesthetic Fluency	11.188	.011
Neuroticism	.847	.838
Extraversion	8.771	.033
Openness to Experience	19.396	< .001
Agreeableness	7.662	.054
Conscientiousness	1.672	.643
Age	14.231	.003
Nausea	9.428	.024

Figure 4.4 displays the patterns of estimated means and their 95% confidence intervals for the significant predictor variables. The patterns of estimated means and comparisons between them offer interesting insights into the ways that the types of gallery visitors differed. Unless noted otherwise, all differences described as significant refer to $p < .05$. The detailed results for all variables and conditions are in the online supplemental material.

For art knowledge, the Revisitor group had significantly higher aesthetic fluency scores than each of the other three conditions. For personality traits, there were significant overall effects for extraversion and openness to experience. For extraversion, the Revisitor group and the Engaged group were both significantly more introverted than the Disengaged group. For openness to experience, the Disengaged group was significantly lower than the other three groups, and the Revisitor group was marginally higher than the Engaged group ($p = .066$).

Feelings of nausea were very low overall, but the Disengaged group reported significantly more nausea than the Typical and Engaged groups. The Revisitor group reported marginally higher nausea than the Typical ($p = .060$) and Engaged ($p = .077$) groups. Finally, for age, the Revisitor group was significantly older than each of the other three groups.

Figure 4.4. Predictors of Latent Class Membership



Discussion

The present work examined the psychology of digital art engagements through the lens of an open-source virtual gallery tool. The increase in digital presence and use of virtual gallery applications by museums (Agostino, 2020; ICOM, 2023) makes this work especially relevant; although museum and arts researchers have a good idea of what art viewing looks like in physical spaces, our understanding of art engagement behaviors in virtual environments is sparse. Our results begin to address these knowledge gaps using a plan of research that was guided by three key questions: (1) What does a virtual gallery visit look like? (2) Can virtual visitors be classified according to their gallery behavior? And (3) how do these classes of visitors differ?

Viewing, Navigation, and Visit Behaviors

As a first step in our research, we sought to obtain rich and theoretically informed quantifications of behavior in the virtual gallery. Overall, the global, viewing, and navigation behaviors captured in the current study showed reasonable participant engagement that were consistent with art engagement behaviors reported previously in both virtual and in-person spaces. Global visit behaviors, namely total gallery time and distance traveled, were consistent with those reported in a previous virtual gallery study with free visit parameters (Rodriguez-Boerwinkle et al., 2023b) as well as studies of museum in-person visitorship that report positively skewed visit durations (Brida et al., 2017; Cotter et al., 2022a). In other words, just like with real spaces, the observation that most people spend relatively little time, but that a few people spend a much longer amount of time, touring museum exhibitions is also present in digital spaces.

In terms of viewing behaviors, the number of artworks viewed was generally high, with most people choosing to view all 24 of the artworks present. Given the paid and unconstrained nature of the study, we see this as a good sign of internal motivation to use virtual galleries and similar experiential applications for art viewing. At around 51% with wide variability, the ratio of time spent viewing artworks relative to the overall viewing time in the virtual gallery mirrors findings (of 48% to 57% in two different data collection periods) from previous art museum work using mobile eyetrackers (Reitstätter et al., 2020).

Parallels between navigation in physical and virtual galleries are also evident in our results. Not yet studied in other research, our finding that people spend about half their time stopped, on average, is reminiscent of Serrell's (1998) study of exhibit behaviors, which found that the majority of exhibition visitors stop at less than half of exhibition elements and that number of stops was correlated with visit length. Serrell (1998) also suggested that stops during exhibit visits represented learning-focused experiences—an expression of visit behavior later dubbed "stopping for knowledge" (Sarasso et al., 2020). The findings here may support and extend the "stopping for knowledge" hypothesis. Increased stopping behaviors in our online sample were more likely in the engaged and revisitor groups, which tended to have higher levels of aesthetic fluency than lower engagement groups. This observation suggests behavioral continuity between real and digital gallery spaces for art perception and learning.

Another parallel between movement in the virtual gallery and real gallery spaces is that the often reported (Bitgood, 2006; Garbutt et al., 2020; Whyte, 1988), but seldom quantified, rightward navigational bias was also seen in our digital environment, despite designing the gallery for movement neutrality. For any given transition from one artwork to another, participants tended to approach the artwork from the left (while facing it) and continue on to view the artwork to the right of it as they progressed through the gallery. Quantifying this movement pattern represents an important refinement to previous observations of rightward movement. Previously, right turns, rightward movement, moving counterclockwise, and approaching artworks or exhibit features from the right have all been used interchangeably in the literature on museum navigation, but do not imply the same behavior. With the aid of OGAR's high movement data precision, we were able to not only observe similar behaviors in the digital gallery space, but also define the behavior more concretely than has been done to date.

Finally, a third parallel is reflected in the curvature of the navigational trajectory that visitors take. Although this variable has only begun to be investigated by psychology of arts researchers, the potential for predicting cognitive and emotional engagement is evident. In a mock gallery space equipped with movement trackers, Kühnapfel and colleagues (2024) linked straighter trajectory paths through the gallery space to a PCA-derived visitor group that was characterized by low affective response to artwork but high awareness of how they physically approached the art in the gallery. In the current study, higher levels of a related (but conceptually opposite) trajectory curvature variable—sinuosity—were a behavioral indicator of more highly engaged groups derived from a latent class analysis, revealing potential for cognitive and emotional engagement prediction.

A final set of deeper engagement behaviors, termed artwork "visiting", was calculated based on the combination of several basic behaviors: looking at an artwork while being stopped closest to it for at least one second after having viewed a different artwork. Overall, people tended to visit about 12 artworks at least once on average, but subsequent visits were far less common. Virtual gallery visitors only revisited about 1 artwork on average, although the median number was zero and there was wide variation in revisits (0-17). Like the rest of the psychology of arts literature, our findings on deep artwork engagements present wide trends, but great individual variability. These findings advance our understanding of behavior in virtual environments as well by investigating behavioral outcomes that have not previously been examined. Our results provide an illustration of the movement in the broader psychology of arts literature to break down complex and meaningful art behaviors into their constituent parts (Linden & Wagemans, 2022) and highlight the affordances of virtual tools as valuable in that pursuit.

Categorizing Visitors via Latent Class Models

Our second aim, to classify our virtual gallery visitors into engagement groups based on eight of the gallery behaviors described above, was conducted using a latent class analysis approach. Considering both the statistical qualities and parsimony of two, three, four, and five class solutions, we found that participant behavior in our sample clustered into one of four distinct patterns of engagement—disengaged, typical, engaged, and revisitor classes. The disengaged class exhibited consistently low engagement with the virtual space, showing the shortest gallery time, least travel, and fewest artworks viewed. Next, the typical class demonstrated engagement that was characterized by average to slightly below average gallery time, distance traveled, and artwork views and visits. Behavior in the engaged group was substantially more positive; this group viewed and visited more art, spent more time stopped, and traveled longer and further in the virtual gallery. Finally, the smallest group, named revisitors, stood out as being highly engaged and were defined by their propensity to revisit artworks, which was uncommon in all other groups. This strategy expanded on our previous investigations of behavior in the virtual gallery (i.e., Rodriguez-Boerwinkle & Silvia, 2023c) and on the more general literature on visitor behaviors in art viewing contexts by examining a broader range of behaviors than has been previously considered. Further, our approach of examining behavioral patterns collectively as opposed to individual behaviors separately recognizes that many of the behavioral pieces that make up a gallery visit do not occur independently.

Latent Class Differences in Individual Difference Variables

As a final step in our analyses, we explored whether behavioral classes were linked to several demographic, personality, and art-related variables. In our sample, members of the revisitor group were likely to be older than members of other groups. Openness and extraversion were also linked to class membership: individuals low in openness to experience were more likely to belong to the disengaged group than the other three groups, and the revisitor and engaged groups were significantly more introverted than the disengaged group. As for art knowledge, the revisitor group also had significantly higher aesthetic fluency scores than any of the other classes. Finally, although reports of nausea were very low in general, the disengaged group experienced significantly more nausea than the typical and engaged groups. Overall, these results offer an interesting peek into how our gallery visitors differed and contribute to a comprehensive profile of each engagement class. Demonstrating how the psychological factors of visitors to virtual museum spaces is linked to meaningful patterns of behavior is key for developing customizable technological experiences that are more immersive engaging (Sundar et al., 2015).

Impacts, Future Directions, and Limitations

This work highlights the richness in experience offered by virtual gallery visits—a context for art engagement that has seen considerable growth in recent years—by identifying a broad range of behaviors characteristic of the gallery experience. It also advances visual arts research by contributing quantitative-based insights into how people interact with digital art spaces.

Broadly, the results of the current study have the potential to guide the design of more immersive and engaging virtual gallery experiences that resonate with diverse audiences in terms of their demographic characteristics, personality, and background in the arts. Since virtual galleries have the potential to expand art access to global audiences (see Rodriguez-Boerwinkle & Silvia, 2023a for an in-depth discussion), better understanding and categorizing behaviors related to engagement in them can lead to digital environment designs that accommodate for different needs and preferences. Such accommodations improve inclusivity to cultural programming and art education and increase the effectiveness of art interventions targeted at well-being.

Future work on this topic could benefit from investigating how image-level characteristics contribute to behavioral experiences in virtual galleries. Crucially, this work provides a foundation for examining digital art experiences through experimentally manipulated virtual gallery designs aimed at promoting specific behavioral and psychological outcomes in target groups. It also offers a paradigm for defining deeply engaged art visits that can be applied to studies of art viewing or visitor behavior in field settings.

Importantly, this work also has limitations. Navigational behaviors in the virtual gallery used in this study are influenced by the movement paradigm used by the tool. Researchers interested in studying movement-related variables in other virtual spaces must consider the movement dynamics of the tool that they are using. For example, virtual gallery spaces utilizing animated interpolation (smooth “teleportation” to a location in the distance) or other non-continuous or constrained movement approaches may not be suitable for this type of work. In addition, since this study was conducted using a remote online sample, differences in participant hardware could not be controlled for and have the potential to impact behavior or experience in the gallery in a non-random way.

CHAPTER V: INTEGRATED DISCUSSION

Altogether, the present dissertation synthesizes three papers that, with my commentary, demonstrate the intellectual development of a novel line of research on experiences in virtual art galleries, undergirded by the development of a toolset designed for this purpose. The selected papers represent a cohesive program of research that aims to answer the question, "where is art?," advances open-source and open-science aims, and tackles important methodological issues in the psychology of art and visitor studies. Each section of this cumulative work represents an ordinal step in this process and culminated in a unique paper that demonstrated the development and expansion of this project while simultaneously tackling some of the psychology of art's biggest questions about museum and gallery visits and visitors.

Immediate Contributions to the Psychology of Art and Aesthetics

As the first systematic series of studies of virtual gallery experiences in the psychology of arts, this line of work has opened the field to examining the psychological experience of art viewing in a previously unstudied context. This move into studying contextualized, digital experiences acknowledges "where" art can be found in the present day by highlighting the need to study modalities that the museum community has already embraced.

In terms of starting to describe digital engagement with art, these studies showed us that, at a basic level, people actually use virtual gallery environments to approach and engage with art when allowed to freely visit such a space. Artwork viewing time and viewing distance are both reflective of results from in-person studies (Carbon, 2017; Clarke et al., 1984; Reitstätter et al., 2020; Smith, 2014). In the case of viewing distance, this variable also follows the same relationship to artwork size seen in studies of art viewing in physical contexts (Estrada-Gonzalez et al., 2020;). Although these findings are not fundamentally "psychological" in nature, these behavioral outcomes are common targets of psychological studies of art. The behavioral similarities in virtual and in-person art gallery visits revealed by these studies suggest that similar psychological processes may be at play in both contexts as well.

In particular, the behavioral similarities observed in the early phases of this research inspired subsequent work involving how individual differences may predict these behavioral outcomes. One stand-out among these variables was openness to experience, which broadly correlated with higher behavioral engagement with artwork in a virtual gallery setting. This finding is a positive sign for investigating psychological experiences in virtual galleries because openness to experience has been repeatedly implicated as a predictor of various creative and artistic processes and outcomes (Kaufman et al., 2016; McCrae, 1987; Tan et al., 2016). The finding that openness to experience plays a role in virtual gallery experiences, then, is in line with the idea that visitors in this context rely on some of the same aspects of the self to evaluate and respond to artworks as people do in other contexts that aesthetic experiences occur.

Extraversion was another individual difference variable that showed notable relationships with behavioral engagement outcomes in the virtual gallery setting used in the present line of research. Despite not showing consistent ties to art engagement in other contexts, virtual gallery visitors that were high in extraversion tended to be broadly less engaged in terms of their behavior in the space. So why does extraversion seem to impact how people interact with art in this context? It is possible that the digital nature of the interaction could be driving these effects. Some studies suggest that comfort in expressing one's self online or through digital interactions is tied to introversion (or low extraversion; Amichai-Hamburger et al., 2002; Ebling-Witte et al., 2007). This may imply that visitors low in extraversion are more comfortable engaging with the virtual gallery experience.

However, more research is needed along two fronts in order to further investigate the extraversion-behavior relationships found in virtual galleries. In particular, future research in this area should try to disambiguate the role of extraversion in virtual gallery environments from comfort with technology and related measures. Alternatively, it is possible that the role of extraversion is simply not well-understood in visit contexts. Although personality has been the subject of some major studies in the arts and aesthetics (Atari et al., 2020; Chamorro-Premuzic et al., 2007, 2009; Furnham & Walker, 2001; Schwaba et al., 2018; Silvia et al., 2015; Silvia & Nusbaum 2011; Swami & Furnham, 2014), it has not been greatly investigated in museum or gallery contexts, due to difficulties with administering long personality surveys in field settings. Only a handful of studies have, so far, attempted this, and they typically focus on openness to experience (Mastandrea et al., 2009; Meyer et al., 2023). Rodriguez and colleagues (2021), however, found that extraversion was marginally related to greater emotional evenness across a museum visit, suggesting engagement characterized by similar intensities of emotion during the course of the visit. Therefore, it could be that extraversion commonly plays a role in engagement with art-viewing environments because art engagement is often a solitary and inward-looking activity, but more research is needed to support this idea.

Finally, the last major area where this research program has contributed to literature on the psychology of art is on how variables related to visits are conceptualized, quantified, and captured. This work emphasizes the importance of examining new variables to study art viewing and navigation to investigate the visit experience as a cohesive whole that is more than simply a series of separate art viewings. In addition, it is also part of a growing trend in the field towards representing meaningful gallery interactions as the culmination of several smaller actions or patterns of behavior. Both of these research trends have the potential to make substantial impact in understanding the complexities of art engagement, and the increasing amounts of study they have received has been made possible by technological developments prevalent in arts research methodologies. In terms of the current line of research, OGAR has enabled behavioral measurements such as movement direction to be quantified, because the system captures a large amount of data to define every aspect of a person's movement. Similarly, improvements in tools like mobile eye-trackers or in-room movement sensors will continue to improve conceptual approaches, because they will be able to provide more information than was previously possible. In the meantime, however, virtual gallery tools are indispensable for developing measures that capture the richness and complexity of art engagement.

Related Developments in the Psychology of Art and Aesthetics

How has this line of work guided research in the psychology of art and aesthetics? Most notably, it has inspired a series of virtual gallery studies aimed at improving well-being and flourishing through engagement with art. More broadly, however, this work has started to impact conversations surrounding context, engagement, and individual aesthetic experiences throughout the literature.

Well-being and Flourishing through Virtual Art Engagement

Interest in investigating the benefits of visual art engagement has multiplied in recent years, with a multitude of studies linking visits to art museums to better physical and mental health, emotional outlook, and social bonding (for a review, see Cotter and Pawelski, 2022). However, many of the people who could arguably benefit the most from these outcomes face considerable constraints in accessing spaces for in-person art engagement. Virtual art galleries, this program of work argues, offer a promising opportunity for considering the flourishing implications of digital art engagement. Further, the virtual interventions that arise from this work could potentially mitigate the accessibility concerns of traditional art museums and leverage the increase in digital offerings by cultural institutions that arose in response to the COVID-19 pandemic (Agostino et al., 2020) to create avenues for flourishing through virtual programming that institutions are already emphasizing.

Together, three studies by Cotter and colleagues (Cotter et al., 2022b; Cotter et al., 2023d; Cotter et al., 2023a) address these aims by investigating the effects of visitation to virtual art galleries created using OGAR. One piece of research (Cotter et al., 2023a) examined the role of immersion in facilitating flourishing outcomes from a virtual gallery intervention designed to encourage slow-looking—the process of looking at a single artwork for an extended period of time (usually 10 minutes or more). In this study, we asked participants engage in 15-minute virtual gallery experiences under one of three conditions directing their looking: engaging in curious slow looking, engaging in mindful slow looking, or engaging in looking however they wished. The curious slow looking condition directed visitors to think about the subject of an artwork of their choosing, the artist, and the intent of that work for 10 minutes. The mindful slow-looking also directed participants to engage with a single artwork of their choosing, but with awareness of their personal thoughts and feelings. The control condition, meanwhile, simply asked participants to view whatever artworks they wished for an unconstrained period of time. Despite no significant differences in immersion or well-being measures between each of the conditions, participants reported increased well-being following the virtual art gallery engagement. Importantly, the level of immersion reported during the visit predicted post-visit well-being and emotional state, suggesting that virtual art engagement, similar to in-person art engagement, may contribute to well-being benefits.

Two other well-being studies conducted using virtual art galleries looked more specifically at the role of repeated visits to OGAR environments. In Cotter et al. (2022b), participants were exposed to either a set of virtual gallery visits with conditions designed to increase immersion or a control condition consisting of reading about art. Immersion was found to be higher in the virtual gallery conditions than during the reading condition, and, further, immersion during the virtual gallery visits predicted several facets of flourishing, including engagement, meaning, and autonomy satisfaction. In a third study, the influence of personality and interest in art on virtual art gallery experiences were explored and then used to examine how visit qualities and individual differences predict well-being. Overall, openness to experience was associated with several visit qualities including immersion, and immersion, in turn, was further associated with well-being (Cotter et al., 2023d) Altogether, the results of these studies support the idea that repeated engagement with digital art through virtual galleries can support psychological flourishing and well-being, and that a key predictor of these outcomes is the immersion that visitor feels during their experience.

Context, Engagement, and Individual Aesthetic Experience

The role of context has come to define much of the psychology of art and aesthetics, which has a particular enthusiasm for conducting work in naturalistic settings (Pelowski et al., 2017). Questions about presentation context have traditionally focused on how the ways in which physical artworks are presented influence the aesthetic experience of that work. Specifically, this area of the literature examines common aspects of museum presentation—curation or hanging style, boundaries or architectural details present in a museum space, lighting, and related information (Pelowski et al., 2017). More broadly, questions of context delve into the genuineness of the art experience (Grüner et al., 2019) or even difference between viewing artwork in a museum context and viewing artwork in hospitals (Lankston et al., 2010) or on city streets (Mitschke et al., 2017). With the rise in digital offerings by cultural institutions and increase in production of art without a physical footprint (i.e., digital or computer-based art), however, comes interest in incorporating these unique contexts into the broader conversation. To that end, the pieces from the present scholarly program have been cited in several recent publications that discuss the digital context.

One study of affective responses to visiting a virtual reality (VR) gallery expanded on findings about openness to experience and art-viewing behavior from Rodriguez-Boerwinkle and Silvia (2023b) by examining how it contributes to affect following a VR gallery visit (Gotthardt et al., 2023). It found that participants with higher openness to experience tended to have higher self-reported aesthetic experience during their visit, which subsequently led to higher positive affect after its conclusion. This lends credence to the idea that the relationship between positive affect and greater aesthetic experience seen after in-person art viewing scenarios (Cuypers et al., 2011; Mastandrea et al., 2019) seems to also be present in virtual art viewing environments.

Jonauskaite and colleagues (2022) also identified the growing research trend in investigating the impact of digital art engagement that this line of work represents and pointed out a need for further study into how to optimize psychological outcomes in this context. To do this, they conducted an applied study of an interactive digital interface for engaging with high-resolution art images and scans. Following two studies using this tool, they found that both laboratory participants and museum visitors reported higher interest, aesthetic pleasure, and feelings of exploration while engaging interactively with digital artifacts than engaging with noninteractive digital or physical artifacts (Jonauskaite et al., 2022). Along with the research presented in this dissertation, these related developments in the literature seek to better understand the digital context, especially compared to more traditional in-person viewing contexts.

Another area where the present work has had substantial impact is in research on engagement with art. It is likely that that engagement or interaction has such prominence in the literature on art because it is associated with greater aesthetic appreciation of objects (Jonauskaite et al., 2022). Increasingly, art engagement has come to be seen as an interactive experience, comprising of both cognitive and embodied exploration. Visitor studies researchers have begun to note the importance of tracking whole patterns from individual visitors across the course of an entire visit to better understand engagement, and they suggest that virtual platforms may provide a good option for accomplishing this (Lee et al., 2022). Similarly, a new paradigm for using movement trajectories to study physical engagement with and movement around an artwork in physical gallery or gallery-like settings has also recently been developed as a dialogue between this line of work and that of Kühnapfel and colleagues (2024). To provide a brief recap of this work as it is discussed in earlier chapters of this dissertation, the authors equipped a laboratory testing room with a high-quality reproduction of a professional-quality artwork and movement trackers placed in two corners to create a mock gallery setting. Then, participants were equipped with mobile eye tracking units and instructed to enter the space and view the artwork. After each visit was complete, participants provided appraisals of the artwork, their emotional and cognitive experience, their subjective awareness of their movements, and their art interest and knowledge. Overall, the researchers found patterns of movement that parallel the movement tracking conducted in OGAR. They also found that these patterns of bodily engagement were linked to experience outcomes like insight.

A final area where this work has guided other developments in the psychology of art and aesthetics is in research on individual aesthetic experiences and the person-level differences that contribute to them. Like much of the literature in creativity, art, and aesthetics, openness to experience has shown itself to be an important predictor of behaviors and experiences in virtual gallery settings (Cotter et al., 2023d; Gotthardt et al., 2023; Rodriguez-Boerwinkle & Silvia, 2023b; Rodriguez-Boerwinkle & Silvia, 2023c). Interestingly, however, the impact of other personality variables such as extraversion, remain unclear. Further studies examining digital art engagement and personality have the potential to contribute to fundamental aspects of personality psychology by adding to our knowledge of what individual differences in personality have a global role in aesthetic processing and what personality differences contribute to context-specific engagement with art. More broadly, the inherently subjective and multimodal nature of art provides a unique stimulus for studying personality, because individual aesthetic experiences are built on cognitive appraisals (Silvia, 2005). This means we can learn a substantial amount about how person-level individual differences shape unique sensory experiences, cognitive processing styles, and emotional reactions to the same stimuli.

Due to its increased control relative to field environments, virtual gallery studies are appropriate for tackling questions in this area. Similar work has been completed by researchers interested in studying the emotional-affective experience of virtual gallery settings—often across multiple timepoints or before and after a visit—where researchers have found that visits to contribute to positive affect and emotional states (Cotter et al., 2023a; Gotthardt et al., 2023).

These studies are in a good position to build measures of individual differences into their virtual gallery paradigms.

Developments in Progress

Amid the flurry of well-being work and other research related to context, engagement, and the individual aesthetic experience that this program of study has advanced, my current focus is on addressing perhaps the biggest question that arts researchers have about virtual galleries: How do virtual gallery experiences compare to in-person ones?

At this point in the current program of research, this question has been addressed somewhat indirectly. For example, we now have support for the idea that navigation in virtual galleries looks similar to in-person ones, with visitors actively approaching and viewing artworks. We also know that more specific measures of behavior, such as art viewing time and viewing distance, both reflect what has been observed in in-person studies and are predicted by similar factors (i.e., openness to experience and abstractness for viewing time and artwork size for viewing distance). However, efforts to directly compare a virtual gallery setting with an in-person gallery setting are only recently underway.

In the summer of 2023, my colleagues and I collected data for a comparative analysis of a mock-gallery environment created by the Empirical Visual Aesthetics lab at the University of Vienna and an equivalent, but virtual, gallery created using OGAR. Each gallery space consisted of a single room with eight professional artworks rented from a local organization. The in-person and virtual gallery spaces were matched according to their architectural dimensions and other features (e.g., doors, archways, and ductwork), wall and floor colors, and artwork size and curation, to create as similar spaces as possible.

A total of 240 student participants recruited from the University of Vienna provided informed consent and were evenly divided into either an in-person condition or an OGAR condition. Procedures for data collection in both conditions included donning a mobile eye-tracking unit, visiting a gallery for an unconstrained amount of time, and then completing some demographic and survey items about the experience. If the participant completed the in-person gallery visit, their movement throughout the space was tracked using a lidar sensor, which uses laser pulses to measure the location of people or objects. If the participant completed a visit to OGAR, their movement and view direction were recorded by the native software.

At the conclusion of data collection and processing, we anticipate being able to make several advancements to the field through our analyses. First, we will be able to make direct comparisons between global visit measures, such as overall visit time, average artwork viewing time, average artwork viewing distance, and total distance traveled in each gallery. These broad comparisons will serve to further validate previous results in the present line of work that were limited in their ability for comparison. Second, we plan to investigate movement in each space in a more focused manner by examining more complex navigational measurements and how patterns of trajectories may be similar or different in each environment. In addition to adding to the relatively sparse literature on embodied art viewing, this more directed study will help the field isolate navigational differences in viewing behavior that occur as a function of being in a virtual setting as opposed to an in-person setting. Third, we will examine artwork ratings and aesthetic emotions that were collected after each gallery visit and relate those to individual differences in art knowledge and interest as well as to differences in gallery condition. Investigating these individual difference and aesthetic judgment variables will expand on earlier studies of how the psychology of the visitor contributes to the aesthetic experience in digital contexts. Finally, we will develop a new methodological approach for mapping gaze in a 3D virtual environment based on 2D screen intersections provided by an eye-tracker. These methodological developments will serve as a blueprint for other researchers interested in employing eye-tracking methods in virtual gallery studies. They will also direct improvements in estimating participant "gaze" proxies in 3D environment tools that are not accompanied by eye-tracking hardware.

Future Directions

The focus of this line of work—on a specific context for studies of art viewing as opposed to a narrower problem in the psychology of arts literature—places it in a good position to contribute to understanding some broad-ranging questions in the field. Thus, although this work could theoretically continue in many directions, I highlight only a few that I find particularly diverse and interesting.

The Social Gallery Visit

Even though most people who visit the museum do so with others (Falk & Dierking, 2000), the current state of the literature on art museum visits has little to offer on the social nature of the museum experience. Museum visitors commonly have different agendas and exhibit behaviors that are either codependent or independent of the partners they visit with. One example of markedly independent behavior is the "visit together—look alone" phenomenon often documented by field researchers in the arts (Christidou, 2016; Smith, 2014). This pattern of behavior, whereby visit partners enter a gallery space together, separate while examining the objects in that space, and then reconnect to discuss a particular display or move on to the next room, is thought to be integral to aesthetic judgement. Further, the degree to which this together-separate-together pattern manifests anecdotally seems to differ from dyad to dyad but has never been the subject of study itself.

Another possibility affecting the social interaction between visit partners in the art museum involves the motivations and expectations of each partner. In his Identity Centered Approach, Falk suggests that museum-goers can be represented by different motivational identities that describe how people are likely to interact, explore, and learn in museums and other cultural institutions (Falk, 2006). These motivational identities—termed the explorer, the facilitator, the professional/hobbyist, the experience seeker, and the spiritual pilgrim—have been examined in individual museum visitors (Cotter et al., 2022a), but not in visiting pairs.

Out of Falk's (2006) motivational identities, the facilitator offers a natural starting point for guiding future work in the social museum visit. This class of visitors are driven to visit the museum by their desire to satisfy the needs or wishes of their visit partner. Broadly, this group might describe committed parents seeking to guide the intellectual growth or their children, loyal romantic partners who want to please their partners, or local visitors aiming to be good hosts to visiting relatives. These individuals often express personal preferences for other activities but choose to facilitate museum visits for the good of those they care about.

A third area of interest in the social gallery visit stems from the idea that visiting dyads often differ in their knowledge and interest in the arts. Greater knowledge in the arts moderates cognitive appraisals of art such that experts find art images to be more interesting and less confusing than novices (Silvia, 2013). Individuals with greater expertise in the arts construe meaning in artwork differently (Bimler et al., 2019) and demonstrate distinct gaze strategies (Francuz et al., 2018; Locher, 1996) that persist across domains (Glazek & Weisberg, 2010). But what happens when visit partners are uneven in their interest and knowledge? In what cases can knowledge be transferred and interest cultivated through social experiences in the gallery? And what social dynamics, if any, hinder this sharing? Better understanding the unique motivations that lead people to choose to attend the art museum with a partner and interact with that partner in certain ways can lead to a greater understanding of learning and meaning-making in the museum and develop socially oriented programming that better reflects how most people visit cultural sites, whether in-person or digital.

Finally, the social nature of art engagement in gallery settings can also be examined through a lens of avoidance. Even as most people choose to visit the art museum with others, interactions with strangers in the form of accidently catching someone's eye, navigating around large tour groups, or even being approached by docents or security guards can impede introspective experiences or induce stress and anxiety in gallery visitors (Pelowski et al., 2014). Although this area of work has received some attention, however, it is still unclear whether and how negative social interactions affect navigational and viewing behavior.

The "visit together—look alone" phenomenon, motivation-based group visit strategies, and negative social interactions represent three possible directions for future work on the social gallery visit where virtual gallery tools may prove useful. Preceded, of course, by investigations of whether each of these phenomena occur in virtual environments, virtual gallery studies of these topics may benefit from several technological affordances. The first potential research line may benefit from the ability of virtual galleries to track the movements of different avatars simultaneously and independently in the environment. In traditional field studies, movement trackers may have trouble with collecting measurements that are fine-grained enough to capture the nuances of close-up interactions between participants or even with differentiating multiple participants and non-participants from one another. Once multi-user tools are enabled in a virtual environment, however, it is trivial to independently track time-based gallery locations for several users at once.

The second future direction in this area, regarding motivations and social engagement, may benefit from the increased recruitment flexibility that lab-based virtual gallery studies can offer. Dyadic or multi-participant studies are difficult to recruit for, and coordinating multiple schedules to align with the opening times or agreed-upon data collection timeframe within a museum adds additional constraint. A virtue of virtual galleries in this situation, therefore, is that they can be used by participants in lab settings, where researchers and participants can schedule according to their needs and make their way through more complex study designs.

The last social phenomenon, that of avoiding others, can also benefit from study in virtual galleries. Namely, simulated visitors or other virtual actors can be placed in the environment, and the interactions (or avoidances) that participants execute during their visit can be tracked. Pre-recorded simulation paths or even generative artificial intelligence models pretrained for study-appropriate conversations can be integrated into the approach to make convincing fake visitors without the need for live-coconspirators. Altogether, these future directions would tackle important outstanding questions about the social gallery visit, but these tools can be applied to questions in other areas as well.

The Neuropsychology of Art Engagement

In addition to looking outward to social experiences during art engagement, researchers can also look inward to the brain. The field of neuroaesthetics aims to understand how engagement with aesthetic objects is expressed in the brain. Topics of study in neuroaesthetics exist at the intersection of cognitive and affective neuroscience and frequently contribute to questions about how we perceive aesthetic objects, make reward-based decisions about them, and experience emotions in response to our engagement with them (Chatterjee, 2015; Chatterjee & Vartanian, 2014; Nadal & Chatterjee, 2018; Pearce et al., 2016).

To this end, many studies have focused on artwork as their preferred aesthetic stimuli. From these studies, we've gathered a diverse range of findings about art. For example, we've learned that different areas of the brain show enhanced activity in response to different types of pleasurable art stimuli (Kawabata & Zeki, 2004), that judgements of aesthetic beauty occur exceedingly fast (400-1,000 milliseconds after stimulus presentation in some cases; Cela-Conde et al., 2009; Munar et al., 2012), and that people's expectations about whether an artwork is genuine or not draw on knowledge or memories that can enhance or dimmish aesthetic pleasure (Lacy et al., 2011; Huang et al., 2011). Despite these knowledge gains, however, this area's common focus on examining neural responses to single artworks as opposed to groups of artworks located in temporally-continuous and visually-contextualized experiences leaves its potential limited.

Future research directions that broaden neuroaesthetic stimuli to include entire visit experiences would enable us to study how decisions to engage with or retract from art are instantiated in the brain. Further, development in this direction would add nuance to our understanding of aesthetic experiences by allowing us to observe how aesthetic experiences grow and change over the course of prolonged engagement with multiple artworks. Understandably, these efforts have been stymied by the physical burdens of neuroscientific tools for probing the brain; fMRI, MEG, and other tools are simply incompatible with traditional field research. Virtual gallery tools, however, have the potential to address these research problems, because they can be used in conjunction with neuroscientific approaches. In this way, they provide us with access to how the brain responds to experiences normally reserved for life outside the scanner. Overall, when viewed as a companion tool that can be paired with any number of methodologies, virtual galleries have the potential to impact psychology of art and aesthetics research in areas far beyond neuroscience as well.

Shared Underpinnings of Diverse Aesthetic Experiences

The aesthetic experience is a highly complex process, thought to have at least five information-processing stages: perceptual analyses, implicit memory integration, explicit classification, cognitive mastering, and evaluation resulting in both aesthetic judgments and emotions (Leder et al., 2004; Leder & Nadal, 2014). This view of aesthetic processing has been widely adopted by arts and aesthetics researchers, with over 3900 citations (combining both of the above articles by Leder and colleagues) spanning everything from the beauty of mathematics (Smith-Miles & Muñoz, 2022) to the evolutionary aesthetics of landscapes (Jacques, 2021). Despite the broad coverage of this model and the considerable number of scholarly works examining each part, there has not been a unified, concentrated effort to systematically study each individual stage.

Virtual galleries may be a uniquely suited toolset for tackling this ambitious effort due to their robust data collection ability, tightly controllable manipulation, and vast possibilities for integration with other technologies. Realistically, this future direction would consist of a program of at least five virtual gallery projects (representing each stage of the model) with multiple studies targeted at experimentally manipulating predictors related to each stage. Achieving this extensive line of work using a single primary tool, while keeping all else as consistent as possible, would greatly add to the interpretability of evidence supporting the model by Leder and colleagues (2004), and it is something that cannot be completed under the constraints of traditional in-person research with physical stimuli. The range of tools needed to study elements from early-stage visual perception to late-stage self-related interpretation, as well as the inability to alter physical art for the purposes of manipulating lower-level perceptual features or upper-level stylistic and content-based features, make other study methods incapable of handling all stages of the model. This limitation necessarily segments our understanding of aesthetic experiences. However, by leveraging the abilities of virtual gallery tools described throughout this manuscript, combined with companion tools like perceptual-cognitive methodologies, psychological self-reports, interview-based qualitative methods, and neuroimaging techniques, it is possible address the entire theoretical framework for aesthetic processing. The result of this work would demonstrate how aesthetic experience can be unified and shared among a diverse literature.

Limitations, Challenges, and Considerations

Predicting the future value and research capabilities of virtual galleries in the psychology of arts is not without risk. To best capture the limitations, challenges, and considerations of using virtual gallery tools in psychological research, I focus on conceptual issues with virtual gallery research in this area more broadly. While many capability-related limitations of virtual galleries—such as the absence of multi-user interactions, the inability to depict 3D or time-based art, or the barrier to use by certain groups—can be built around during the development process, the points raised in this section are more perceptual in nature.

First, virtual gallery studies shouldn't be thought of or used as a strict replacement for traditional field work in art museums and contexts for art engagement. Although existing virtual gallery research has begun to show preliminary similarities in visits to physical and virtual spaces, many aspects remain distinct. In the museum, for example, the physiological processes of movement are not the same as movement in virtual environments. As a result, even if the outcomes (i.e., navigational behavior) appear similar, it should not be assumed that the same underlying processes are at play. On the other hand, virtual galleries, too, have special features, such as zoom-in tools or other means of interactivity, that make these experiences unique from in-person ones. To view virtual and physical galleries as a one-to-one comparison is a limitation in this framework. More naturally, research is made more robust if these modalities are investigated in parallel or chosen on a study-by-study basis for their strengths. Just like with tools in other areas of psychology, some study questions and research constraints may lend themselves to one modality or the other.

Second, no single virtual gallery tool can do it all, and no virtual environment is strictly like another. Currently, OGAR is the only tool "on the market" designed for research use. While this marks a methodological advancement in the psychology of arts literature, this shouldn't remain the case. If "a worker is only as good as their tools," then so are academic fields. If OGAR remains the only tool in use by psychology of art researchers, then the limitations of the tool will come to be seen as limitations of virtual gallery research more broadly. There is a need to develop other toolsets better suited to other research uses, such as virtual gallery software that is geared toward working with mobile interfaces or that is compatible with immersive virtual reality headsets. There is also a need to recognize that because virtual galleries don't all have the same affordances, they need to be built or chosen with specific research use in mind. Perhaps the easiest way to ensure that researchers have the choices they need to select tools that fit their research is to prioritize keeping research software like OGAR opensource, with permissive licensing. This consideration helps a create cultural standard geared toward opensource and open science aims among researchers who are interested in working with virtual galleries and provides the environment needed to branch OGAR into other successful research tools.

Third, those interested in understanding how we experience art should be prepared to drop preconceptions about where they might find art experiences. Some people believe that in-person spaces for art engagement are imbued with a level exceptionalism or sacredness that virtual environments for art viewing can simply never achieve or compare with. It is worth noting that this is not a new idea; scholars like Walter Benjamin and Philip Fisher shared similar concerns about the decontextualization inherent in moving art from homes, churches, and public places to museums (Branham, 1994). This romanticization of art engagement represents a challenge to empirically understanding how we interact with all art—not just digitally-presented art. Instead of relying on conventional wisdom that injects spaces like 10 m^2 of standing room surrounding the Mona Lisa with psychological sacredness, researchers need to embrace research that really seeks to answer the question, “where is art?”

Conclusions

Thus far, this work has described the development of a tool for studying virtual art gallery visits and demonstrated how this class of tools can make strides in the psychology of art. In addition to providing a new and relevant context in which to study art, I discussed how virtual gallery tools can be used to collect rich, quantitative data that supports the use of new measures across arts research. I also pointed out how virtual galleries can be used, especially in conjunction with other diverse tools and methods, to tackle some of the field’s biggest psychological questions. Finally, I highlighted the most pressing conceptual and perceptual concerns undermining this research area. Altogether, this work reveals the shared and surprising psychology of the virtual art gallery visit and how this area is poised to guide the future of research on art and aesthetics.

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APPENDIX A: ADDITIONAL TABLES

Table A1. List of Artworks used in Chapter II

Number	Title	Artist	Year	Room	Representational?
1	Lita Curtain Star	Andy Warhol	1968	1	Yes
2	Woman with a Fan	Pablo Picasso	c. 1905	1	Yes
3	Water Lilies	Claude Monet	1906	1	Yes
4	Untitled (Green and Red)	Fiona Rae	1994	1	No
5	Terrano X	Emil Schumacher	1990	2	No
6	Starry Night	Vincent van Gogh	1889	2	Yes
7	Broadway Boogie Woogie	Piet Mondrian	1943	2	No
8	Painting Number 2	Franz Kline	1954	2	No
9	Untitled	Willem de Kooning	1988	2	No
10	Solitary Tree	Caspar David Friedreich	1822	2	Yes
11	Untitled	Per Kirkeby	2012	2	No
12	Eyes in the Heat	Jackson Pollock	1946	1	No
13	Reclining Girl	François Boucher	1752	1	Yes
14	Untitled	Mark Rothko	1954	1	No

15	The Silver Goblet	Jean-Baptiste-Siméon Chardin	1728	1	Yes
16	Hare	Albrecht Dürer	1502	2	Yes

Table A2. Descriptive Statistics by Artwork for Chapter III

						Viewing Time			Viewing Distance		
VAP S #	**Art Name**	**Artist**	**Year**	**Area (m^2)**	**Representational?**	**Mean**	**Median**	**SD**	**Mean**	**Median**	**SD**
20128	Sommer	Arcimboldo, Giuseppe	1563	0.34	Yes	4.25	2.4	6.37	1.39	1.04	1.13
20309	Portrait of a Black Man	Gericault, Théodore	1822-23	0.17	Yes	2.25	0.6	4.17	1.47	1.04	1.23
50833	Abstract Composition	Wadsworth, Edward	1915	0.14	No	2.06	0.2	4.94	1.43	0.91	1.58
50703	Rising Sun	Klee, Paul	1919	0.08	No	3.06	1	7.13	1.06	0.59	1.36
51002	Lake George, Coat and Red	O`Keeffe, Georgia	1919	0.40	No	2.93	0.8	6.32	1.87	1.34	1.54
10515	The Pirates	Slevogt, Max	1914	0.69	Yes	4.02	2.2	5.88	1.75	1.25	1.53
51104	Man Looking at Woman	Gottlieb, Adolph	1949	1.46	No	5.82	2.1	27.86	2.60	2.13	1.83

50811	The Passage from Virgin to Bride	Duchamp, Marcel	1912	0.32	No	3.18	1	6.18	1.58	1.05	1.50
30221	Vienna seen from the Belvedere	Canaletto/Bellotto , Bernardo	1758	2.91	Yes	10.41	6.6	13.85	2.81	2.04	2.21
20605	Woman with a Parasol	Signac, Paul	1893	0.53	Yes	3.45	0.2	8.19	1.95	1.48	1.40
41024	Skull with Candle	Richter, Gerhard	1983	0.56	Yes	3.39	0.8	5.65	1.73	1.39	1.28
50901	Composition	Lissitzky, El (Eliezer)	1922	0.43	No	2.35	0.4	4.12	2.03	1.53	1.56
31017	Subway	Estes, Richard	1969	0.18	Yes	3.48	1.8	4.66	1.15	0.73	1.20
11026	Barbecue	Fischl, Eric	1982	4.19	Yes	9.32	6	12.13	3.89	2.85	3.02

51326	Lysander I	Olitski, Jules	1970	7.78	No	5.92	3.6	7.54	5.38	4.66	2.73
51115	Bather	Miro, Joan	1932	0.17	No	2.12	0.2	4.93	1.24	0.91	1.06
11019	Repression	Rivera, Diego	1931	3.30	Yes	6.45	4	8.02	2.62	2.09	1.64
51301	Quattro Stagioni, Autunno	Twombly, Cy	1993-95	5.96	No	6.33	3.4	10.61	3.56	2.93	1.90
51215	Soul of the Underground	Dubuffet, Jean	1959	2.92	No	4.95	2.6	8.96	2.82	2.31	1.63
50940	Praise I	Riley, Bridget	Unknown	2.36	No	3.83	2.1	6.56	3.25	2.60	2.03
31103	Blood with Tell	Magritte, René	1959	1.03	Yes	6.08	3	9.01	2.20	1.41	2.00
40704	Still Life with Flowers and Oranges	Jawlensky von, Alexej	1909	0.41	Yes	2.73	1	4.40	2.00	1.22	2.14
40405	Dessertfrüchte mit Elfenbeinhumpe	Preyer, Johann Wilhelm	1838	0.30	Yes	9.17	6.4	10.77	2.58	2.04	1.55

	n										
51013	Dr Feel Good - Clermont Ferrand	Villeglé de la, Jacques	2000	4.14	No	6.69	4	9.29	2.94	2.40	1.61

Note. Artwork viewing time reported in seconds. Artwork area reported in square meters.

Table A3. Descriptive Statistics and Pearson Correlations for Continuous Study Variables in Chapter III

	M (SD)	***Median***	***Min/Max***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1. Age	33.85 (12.30)	32	18, 69	1											
2. Visit Time	3.91 (3.00)	3.05	.17, 18.97	.32	1										
3. Distance Traveled	118.83 (55.50)	114.92	9.95, 412.38	.19	.70	1									
4. % Time Viewing Art	0.51 (0.19)	0.51	0.03, 0.91	-.40	.17	.22	1								
5. Nausea	1.49 (1.10)	1	1, 7	.08	.03	.02	-.22	1							
6. NEO Agreeableness	3.63 (0.50)	3.67	2.17, 4.75	.10	.17	.16	-.02	.02	1						
7. NEO Conscientiousness	3.38 (0.69)	3.33	1.25, 5.00	.20	.02	.02	-.05	.00	.13	1					

8. NEO Extraversion	2.88 (0.62)	2.92	1.17, 4.92	-.12	-.17	-.15	-.08	-.11	.08	.29	1				
9. NEO Neuroticism	3.34 (0.82)	3.42	1.08, 4.92	-.31	-.02	.05	.10	.11	-.13	-.53	-.39	1			
10. NEO Openness	3.89 (0.51)	3.92	2.00, 4.92	-.03	.21	.19	.11	.01	.20	.09	.07	.10	1		
11. Aesthetic Fluency	0.59 (0.36)	0.50	0, 1.83	.24	.19	.12	-.06	.03	.13	.04	.02	.06	.42	1	
12. Aesthetic Responsiveness	2.09 (0.72)	2.07	0.21, 3.93	-.03	.16	.09	.02	.08	.13	.07	.17	.12	.63	.54	1

Note. n = 264. The descriptive statistics are for the raw scores; for the analyses, transformed versions of visit time, distance traveled, and percent time viewing art were used. The NEO items were completed using a 5-point, 1-5 scale. Aesthetic Responsiveness was completed using a 5-point, 0-4 scale. Pearson *r* coefficients are reported.

Table A4. List of Artworks used in Chapters III and IV

Study Number	VAPS File Number	Title	Artist	Year	Artwork Area	Representational?
1	10515	The Pirates	Slevogt, Max	1914	.70	Yes
2	11019	Repression	Rivera, Diego	1931	4.49	Yes
3	11026	Barbecue	Fischl, Eric	1982	4.19	Yes
4	20128	Sommer	Arcimboldo, Giuseppe	1563	.34	Yes
5	20309	Portrait of a Black Man (Portrait of a Negro)	Gericault, Théodore	1822-23	.17	Yes
6	20605	Woman with a Parasol	Signac, Paul	1893	.53	Yes
7	30221	Vienna seen from the Belvedere	Canaletto/Bellotto, Bernardo	1758	2.91	Yes
8	31103	Blood with Tell (La voix du sang)	Magritte, René	1959	1.03	Yes
9	31017	Subway	Estes, Richard	1969	.18	Yes

10	40405	Dessertfrüchte mit Elfenbeinhumpen	Preyer, Johann Wilhelm	1838	.30	Yes
11	40704	Still Life with Flowers and Oranges	Jawlensky von, Alexej	1909	.41	Yes
12	41024	Skull with Candle	Richter, Gerhard	1983	.56	Yes
13	50703	Rising Sun	Klee, Paul	1919	.08	No
14	50811	The Passage from Virgin to Bride	Duchamp, Marcel	1912	.32	No
15	50833	Abstract Composition	Wadsworth, Edward	1915	.14	No
16	50901	Composition	Lissitzky, El (Eliezer)	1922	.43	No
17	50940	Praise I	Riley, Bridget	unknown	2.36	No
18	51002	Lake George, Coat and Red	O`Keeffe, Georgia	1919	.40	No
19	51013	Dr Feel Good - Clermont Ferrand (Décollage)	Villeglé de la, Jacques	2000	4.14	No
20	51104	Man Looking at Woman	Gottlieb, Adolph	1949	1.46	No

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21	51115	Bather	Miro, Joan	1932	.17	No
22	51215	Soul of the Underground	Dubuffet, Jean	1959	2.92	No
23	51301	Quattro Stagioni, Autunno	Twombly, Cy	1993-95	5.96	No
24	51326	Lysander I	Olitski, Jules	1970	7.78	No

Note. Artwork area reported in square meters. Table reproduced from Rodriguez-Boerwinkle and Silvia (2023c).