Introducing the Wunderkammer as a Tool for Emotion Research:

Unconstrained Gaze and Movement Patterns in Three Emotionally Evocative Virtual Worlds

Cade McCall\*^, Lea K. Hildebrandt^, Ralf Hartmann, Blazej M. Baczkowski, & Tania Singer

Social Neuroscience Department, Max Planck Institute for Human Cognitive and Brain Sciences

^Joint first authors

\*corresponding author: Cade McCall, Max Planck Institute for Human Cognitive and Brain Sciences, Department of Social Neuroscience, PO Box 500355, 04303 Leipzig, GERMANY, [mccall.cade@gmail.com](mailto:mccall.cade@gmail.com)

Acknowledgments:

The study was funded by the European Research Council under the European Community’s Seventh Framework Program (FP7/2007-2013/ ERC Grant Agreement Number 205557 to Tania Singer and the Max Planck Society. Additionally, the work carried by Blazej M. Baczkowski was financially supported by the European Science Foundation (ESF), in the framework of the Research Networking Programme - European Social Cognition Network 2 (ESCON 2).

**Abstract**

Here we introduce the “Wunderkammer”, a suite of immersive virtual worlds with different types of emotionally-charged content. We use these worlds to examine the effects of affective context on unconstrained gaze and movement. In the Affect Gallery, participants freely explored a virtual art museum filled with objects that varied in valence and arousal. Participants approached and gazed more at positively valenced objects. This preference was amplified by more arousing objects and was strongest among individuals with resilient emotion regulation tendencies. This bias of avoiding negative valence did not emerge in The Crowded Room, an environment in which participants encountered virtual humans expressing different emotions. Instead, participants gazed more at negative than neutral emotional displays although they physically avoided angry (but not sad or neutral) agents. When placed inside Room 101, an unpredictable environment filled with a series of disturbing events, frightened participants became relatively immobile in terms of both gaze and movement. This freezing-type response was particularly strong among dispositionally resilient individuals. Together these results demonstrate that distinct affective contexts elicit unique patterns in unconstrained gaze and movement. They further illustrate the benefits of using virtual reality to study affect as it naturally emerges.

Keywords: virtual reality, threat, affect, emotion, emotion regulation, behavioral methods

**1. Introduction**

We live in complex worlds full of people and things that we find desirable, repulsive, interesting, and dull. These feelings about our surrounding environments determine our behavior as much as any physical constraints. Accordingly, we automatically make inferences about a person’s inner states simply from watching what and whom they approach, avoid, attend to, and ignore (e.g., [Ambady & Rosenthal, 1992](#_ENREF_3); [Heider & Simmel, 1944](#_ENREF_43)). If a woman stops and stares at a painting, we might say she is transfixed. If a couple leans close over a candlelit dinner, we guess they are in love. If a child freezes, wide-eyed, when he sees a barking dog, we assume he is afraid. Intuitively we use others’ movement through the world and the direction of their gaze to infer their motivational and emotional states.

Nevertheless, experimental psychology rarely studies unconstrained gaze and movement in naturalistic, emotionally rich environments ([for discussion of methods in emotion research see Quigley, Lindquist, & Barrett, 2014](#_ENREF_79)). Instead, we rely on highly artificial tasks that focus on an extremely limited range of behaviors (e.g., reaction time tasks). Those tasks are furthermore performed in pared-down environments with minimal stimuli and minimal opportunities for exploration and interaction (e.g, desktop paradigms presenting pictures of faces). These traditional laboratory approaches are clearly necessary for experimental control; they help us hone in on basic social and affective processes. But they don’t necessarily tell us how people behave in everyday life ([Kingstone, Smilek, & Eastwood, 2008](#_ENREF_57)). They underestimate the powerful role of context in affect ([Barrett, Mesquita, & Gendron, 2011](#_ENREF_9); [Gendron & Barrett, 2009](#_ENREF_34)). Moreover, they ignore the abundance of information about a subject that is expressed as they move freely through the world, examining their surroundings.

In the current study we used the Wunderkammer, a newly developed suite of immersive virtual environments, to bridge this gap between experimental control and ecological validity. The rooms within the Wunderkammer manipulated affective context in a variety of different manners. Here we used those contexts to examine how different affective features of an environment differentially influence unconstrained gaze and movement as well as to examine how these behaviors are further shaped by individual differences in emotion regulation.

**1.1. Affect in complex environments**

The affective nature of an environment can of course vary in many ways. Here we explore three: the valence and arousal of inanimate objects within the environment, the emotions of other people in the environment, and the threatening nature of the environment itself.

**1.1.1. The valence and arousal of inanimate objects.** Decades of research on the psychology of attitudes demonstrate that people quickly and consistently evaluate objects as positively or negatively valenced ([Albarracin, Johnson, & Zanna, 2014](#_ENREF_2); [Eagly & Chaiken, 1993](#_ENREF_26)). One core function of these attitudes is to prepare the body to act ([Darwin, 1965](#_ENREF_24); [W. James, 2011](#_ENREF_53)); positive attitudes automatically prepare us to engage in approach-related action and negative attitudes prepare us to engage in avoidant-related action ([Chen & Bargh, 1999](#_ENREF_20); [Markman & Brendl, 2005](#_ENREF_62); [McCall, Tipper, Blascovich, & Grafton, 2012](#_ENREF_68)). In this sense, attitudes are not simply abstract evaluations, but are embodied in our behavior ([Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005](#_ENREF_72)). This fact leads to the intuitively obvious prediction that when freely exploring an environment that is full of both negatively and positively valenced objects, individuals should generally approach the positive objects and avoid the negative ones.

The embodied nature of attitudes is less clear when it comes to gaze. One might expect people to be driven by hedonic goals, preferentially gazing at positive versus negative objects ([Margaret M Bradley, Costa, & Lang, 2015](#_ENREF_15)). While this may generally be the case, dispositional or situational differences may motivate individuals to focus on far more than just the positive features of an environment. One might seek to explore one’s surroundings more broadly or even to focus on negative content that is mood congruent or informative ([Brosch, Sander, Pourtois, & Scherer, 2008](#_ENREF_17); [Isaacowitz, Toner, Goren, & Wilson, 2008](#_ENREF_49); [Vuilleumier, 2015](#_ENREF_90)). One individual difference that likely plays an important role in determining these biases is the individual’s tendency to use their surroundings to regulate their emotions via strategic situation selection or attentional deployment ([J. Gross, 1998](#_ENREF_37)). In the context of exploring one’s environment, situation selection or attentional deployment would take the form of focusing on positively valenced, and ignoring negatively valenced, objects within the environment ([Rinck et al., 2015](#_ENREF_80); [Rovenpor, Skogsberg, & Isaacowitz, 2013](#_ENREF_81)). Eye-tracking research suggests that individuals motivated to increase or maintain positive mood do so by directing their gaze towards or away from negative portions of images ([Isaacowitz, et al., 2008](#_ENREF_49); [Isaacowitz, Toner, & Neupert, 2009](#_ENREF_50); [Isaacowitz, Wadlinger, Goren, & Wilson, 2006](#_ENREF_51)). Along the same lines, individuals who actively regulate their emotions might be more likely to focus on positive objects when freely exploring an environment with a variety of stimuli.

Although arousal is another core feature of affective experience (e.g., [M. M. Bradley & Lang, 1994](#_ENREF_16); [Russell, 2003](#_ENREF_82)), it is not clear how the arousing nature of objects within an environment should affect gaze or movement behavior. On one hand, arousing stimuli capture attention ([Anderson, 2005](#_ENREF_4); [Arnell, Killman, & Fijavz, 2007](#_ENREF_5); [Keil & Ihssen, 2004](#_ENREF_56); [Lundqvist, Juth, & Öhman, 2014](#_ENREF_60)) and appear to be prioritized in terms of cognitive processing ([Mather & Sutherland, 2011](#_ENREF_64)). As such, one would predict that arousing objects in a novel environment will initially draw an individual’s gaze. However it is not clear that those same objects will hold one’s attention. On the contrary, if the processing of high arousal stimuli is prioritized, then those stimuli should be more efficiently evaluated as positive or negative. This more efficient processing of valence might, in turn, amplify the effects of valence. In other words, highly arousing objects might elicit stronger approach/avoidance and differential gaze patterns than less arousing objects. This claim, however, remains untested.

**1.1.2. Affect in the social environment.** For most of us, some of the most emotionally evocative stimuli in our environments are people (e.g., [Norris, Chen, Zhu, Small, & Cacioppo, 2004](#_ENREF_73); [Olsson & Ochsner, 2008](#_ENREF_74)). Decades of research in social psychology and neuroscience demonstrate that social stimuli are unique in how they are processed, the affective responses they trigger, and the behaviors they elicit (e.g., [Adolphs, 1999](#_ENREF_1); [Baron-Cohen, Lombardo, Tager-Flusberg, & Cohen, 2013](#_ENREF_8); [Fiske & Taylor, 2013](#_ENREF_28)). Responses to the nonverbal expressions of emotions provide a key example of this fact. Regardless of their negative valence, faces expressing anger, fear and sadness, attract and hold attention ([Batty & Taylor, 2003](#_ENREF_10); [Green & Phillips, 2004](#_ENREF_36); [Lundqvist, et al., 2014](#_ENREF_60); [Palermo & Rhodes, 2007](#_ENREF_75)), most likely because they provide not only information about the affective state of the target but also alert one to potential threats in the environment ([e.g., Hansen & Hansen, 1988](#_ENREF_41)). Given that, if one encounters an individual in everyday life and that individual is clearly expressing an emotion, positive or negative, one’s gaze is likely to be drawn to that individual.

The power of emotional expressions to draw one’s gaze, however, need not correspond with physical approach. On the contrary, the very reason that an angry face captures our attention may be the same reason that we avoid the person wearing that expression. Anger, particularly when it is directed towards us, marks a threatening individual whom we are better off avoiding (or in extreme cases, attacking). As such, nonverbal expressions of anger provide an excellent test of the dissociability of gaze and approach behavior within a complex environment. Individuals should attend to angry or threatening others, but physically avoid them.

**1.1.3. Threatening environments.** Threats are not always isolated to individual objects or people within an environment. Sometimes an entire environment is threatening. Imagine walking down a crowded street during an earthquake. Danger is omnipresent but does not have a specific location; bricks could fall from the sky, cars could veer off of the road, or the ground itself could crack beneath you. In this situation one cannot ignore or avoid a single, specific target. Instead, one is faced with pervasive and frightening uncertainty. Although this type of context is an important feature of human experience, we know little about how pervasive and unpredictable environmental threats affect human behavior.

Nevertheless, evidence from the animal literature provides us with some clues. Ethologists have long discussed the role of freezing in non-human primates’ response to threats ([Gray, 1987](#_ENREF_35)). Freezing reduces the likelihood of detection by a predator and, further, allows the prey to assess the situation. The traditional model of the response to threat based on the animal literature describes a cascade of behavior in a threat response continues from freezing to “fight or flight” ([Cannon, 1929](#_ENREF_18)) which, of course, are not always possible. Next, the prey can enter a phase of “tonic immobility”, also known as “playing dead” ([Gallup Jr, 1974](#_ENREF_32)) whereupon the body goes slack.

In recent years Bracha and others have discussed this cascade and how it might pertain to human psychophysiology and behavior ([Bracha, 2004](#_ENREF_14); [Marx, Forsyth, Gallup, & Fusé, 2008](#_ENREF_63); [Misslin, 2003](#_ENREF_69)). In the absence of opportunities for fight and flight, as when one is trapped in a threatening environment, humans might also respond with a combination of freezing and tonic immobility ([Bracha, 2004](#_ENREF_14); [Marx, et al., 2008](#_ENREF_63)). Accordingly, a handful of experiments in neuroscience and psychiatry have found preliminary evidence for both of these. One study induced threat via oxygen deprivation and found subjective reports of both freezing and immobility among participants, both of which were related to fear during the experience ([Schmidt, Richey, Zvolensky, & Maner, 2008](#_ENREF_87)). Another study found that participants’ reaction times during a task slowed down when they were exposed to images of threatening stimuli (e.g., spiders and snakes) that appeared to be coming towards them, an effect that was particularly strong among participants experiencing anxiety ([Sagliano, Cappuccio, Trojano, & Conson, 2014](#_ENREF_84)). Together, the research suggests that when individuals are in the midst of a threatening and uncertain environment, they will slow their movement and that this effect will be particularly strong amongst those subjectively experiencing fear or anxiety. Nevertheless, the literature on how this very basic phenomenon functions in humans is spare and none of it examines how unconstrained and task irrelevant behavior unfolds in the midst of such an environment.

It is also unclear how this relatively primitive freezing response might relate to more distinctly human and “higher level” psychological responses. The psychology literature on emotion regulation has examined a variety of processes by which individuals regulate their affective responses to distressing situations ([James J Gross, 2015](#_ENREF_39); [James J Gross & Thompson, 2007](#_ENREF_40)). At first blush, one might assume that individuals high in the ability to regulate their emotions (i.e., to reduce negative affect and physiological stress) would simply experience less fear. Upon closer inspection, the strategies we associate with healthy emotion regulation—strategically selecting situations to avoid distress or reappraising situations in a positive light ([Carver, Scheier, & Weintraub, 1989](#_ENREF_19); [James J. Gross, 2001](#_ENREF_38); [James J Gross & Thompson, 2007](#_ENREF_40)) --might be difficult to deploy in a context in which one has nowhere to turn and nothing positive in the environment upon which to focus. Moreover, no matter how skilled we are at regulation or how generally resilient we are, all of us face situations in which we are afraid. Within such contexts, it is not clear if deliberative emotion regulation strategies would affect the classic and relatively automatic threat cascade described by the animal literature (i.e., from the perception of a threat to tonic immobility) . In this sense, the link between the psychology of emotion regulation and the animal literature’s classic formulation of the stress response requires exploration.

Together this brief review of the literature suggests that different affective features of the environment should differentially influence gaze and movement. These patterns should emerge across individuals but should also reflect individual differences in emotional experience and regulation. Nevertheless, the literature provides little evidence for how behavior emerges, spontaneously and unconstrained, within complex and emotionally evocative environments. This shortcoming is most likely due to the limits of traditional, laboratory-based approaches to studying human affect.

**1.2. Virtual Ethology**

Researchers from a variety of domains have long argued for more naturalistic approaches to psychology ([Conner, Tennen, Fleeson, & Barrett, 2009](#_ENREF_22); [Henderson, 2003](#_ENREF_44); [Isaacowitz & Stanley, 2011](#_ENREF_48); [Kingstone, et al., 2008](#_ENREF_57); [Schilbach et al., 2013](#_ENREF_86)). For example, Kingstone and colleagues ([Kingstone, et al., 2008](#_ENREF_57)) argue that basic psychological research should begin by studying processes as they naturally occur, unconstrained and embedded in complex real-world environments. Findings from this ethological approach can, in turn, inform the design of more traditional laboratory paradigms ([Chisholm et al., 2014](#_ENREF_21)). However, an ethological approach presents two clear challenges if one is to remain within the controlled confines of the traditional laboratory: 1) the challenge of constructing naturalistic contexts and, 2) the challenge of measuring psychological responses as they unfold within those contexts.

Virtual environments allow us to address both of these challenges.Participants can come to the laboratory and be immersed in worlds that simulate the complexity and richness of everyday life ([Blascovich & Bailenson, 2011](#_ENREF_11); [Morie, Iyer, Luigi, Williams, & Dozois, 2005](#_ENREF_70); [Slater, Pertaub, & Steed, 1999](#_ENREF_89)). Experimenters can place socially anxious people in the midst of a crowd ([L. K. James, Lin, Steed, Swapp, & Slater, 2003](#_ENREF_52)), arachnophobic individuals in the presence of spiders ([Parsons & Rizzo, 2008](#_ENREF_76); [Peperkorn, Diemer, & Mühlberger, 2015](#_ENREF_77); [Rinck, et al., 2015](#_ENREF_80)), or romantic partners in a dangerous situation ([Kane, McCall, Collins, & Blascovich, 2012](#_ENREF_54)). These and other examples ([Fox, Arena, & Bailenson, 2009](#_ENREF_31); [McCall & Blascovich, 2009](#_ENREF_65)) illustrate that we can create naturalistic experiences without sacrificing the experimental control afforded by the laboratory. Although virtual environments require some software development and the appropriate hardware, they can be re-used and shared, making replication across time and laboratories relatively straightforward ([Blascovich et al., 2002](#_ENREF_12)),

The second challenge to an ethological approach to laboratory-based emotions research is measurement. How do we measure psychological responses in naturalistic situations without interrupting or biasing their outcome? One place to begin is by simply observing behavior ([Kingstone, et al., 2008](#_ENREF_57)). As the previous section describes in detail, gaze and movement are two categories of behavior that are likely to reflect a host of affect processes. In recent research, virtual environments have proven useful in measuring these behaviors. Digital motion tracking provides precise and continuous measurement participants’ position and orientation over the course of an experience in an immersive virtual world ([Bailenson, 2003](#_ENREF_7)). Moreover, these data can be gathered implicitly, without interfering with the participants’ experience or requiring a conscious or deliberative response. Accordingly, these gaze and position tracking have proven useful in the study of affect in the midst of social interactions ([Dotsch & Wigboldus, 2008](#_ENREF_25); [McCall, Blascovich, Young, & Persky, 2009](#_ENREF_66); [McCall & Singer, 2015](#_ENREF_67)).

Together, this brief overview of existing research makes clear that immersive virtual environments provide a platform to both create naturalistic contexts and to study behaviors, specifically gaze and movement, as they spontaneously emerge within those contexts. In this sense, virtual reality allows us to take an ethological approach to studying human affect without abandoning the controlled setting of the laboratory. Here we make use of that capability.

**1.3. Hypotheses**

The Wunderkammer is a suite of virtual worlds that vary in the affective nature of their content. We used these worlds to study the influence of different affective features of the environment on unconstrained gaze and movement. We further tested how these behavioral responses were moderated by individual differences in the degree to which individuals employ resilient emotion regulation styles. Our hypotheses were as follows:

**1.3.1. Hypotheses for The Affect Gallery**. The Affect Gallery is a virtual art museum filled with images that vary both in terms of valence (positive versus negative) and arousal (high versus low). We used the Affect Gallery to test the hypothesis that when given the opportunity to freely explore, an individual’s gaze and movement with respect to inanimate objects will generally be guided by hedonic goals; i.e., individuals will gaze at and move towards positively valenced images as compared to negatively valenced images. We further predicted that since the arousing nature of inanimate objects should attract attention and facilitate processing of valence (e.g. [Lundqvist, et al., 2014](#_ENREF_60); [Mather & Sutherland, 2011](#_ENREF_64)), biases toward positive and away from negative images would be stronger for high versus low arousal images.

In addition to those within-subjects hypotheses, we also predicted that individual differences in emotion regulation tendencies would influence behavior. Given the notion that individuals strategically regulate their emotions by directing gaze away from negative content ([e.g., Isaacowitz, 2006](#_ENREF_46)), we predicted that individuals high in the tendency to engage in healthy emotion regulation strategies would show a more dramatic valence bias, gazing more at and approaching positively valenced images more than negatively valenced images.

**1.3.2. Hypotheses for The Crowded Room.** The Crowded Room is a virtual world in which participants encountered three agents nonverbally expressing three different emotional states: anger, sadness, and a neutral state. Because emotional expressions attract and hold attention ([Batty & Taylor, 2003](#_ENREF_10); [Green & Phillips, 2004](#_ENREF_36); [Lundqvist, et al., 2014](#_ENREF_60); [Palermo & Rhodes, 2007](#_ENREF_75)), we predicted that participants would spend more time looking at the sad and angry agents. However, this bias towards attending to the emotive agents should not necessarily be coupled with a bias towards approach given that anger, in particular, signals a threat ([Hansen & Hansen, 1988](#_ENREF_41)). Accordingly, we predicted that participants would physically avoid angry, but not sad or neutral agents.

As with The Affect Gallery, we also hypothesized that these effects would be moderated by emotion regulation tendencies. Specifically, we predicted that individuals high in the tendency to deploy emotion regulation strategies would physically avoid looking at and approaching the negatively valenced (sad and angry) agents.

**1.3.3. Hypotheses for Room 101.** Room 101 is a virtual world in which the participant confronts a series of disturbing and unpredictable events including explosions, gunshots, an infestation of spiders, and a collapsing floor. Using Room 101, we tested the notion that fear within such an environment would lead to immobilization (i.e., freezing and/or tonic immobility). Specifically, we predicted that participants who found the world frightening would walk and look around more slowly, particularly during the portions of the world in which more disturbing events occur.

In terms of individual differences, we predicted that participants high in healthy emotion regulation would find the world less frightening. As for the influence of fear on movement and gaze among these individuals, we had no concrete predictions. We nevertheless tested whether healthy regulators were more or less likely to be immobilized by fear.

**1.3.4. Hypotheses for The Panopticon.** The Panopticon is an additional room in the Wunderkammer that does not manipulate or measure any affect-related phenomena, but measures visual detection. The room is full of many objects (e.g., pictures, lamps, wall panels, and etc.), half of which are gradually changing at a barely detectable rate. The participant’s task was to identify as many of those changing objects as possible. The score on this task thus provided a gauge of the participant’s ability to detect events in a complex, three-dimensional environment.

The Panopticon was not designed to study affect per se, but we include it here as a post-hoc control for basic differences in visual detection abilities for two different reasons. First, we used gaze behavior in The Panopticon to test a the basic assumption that gaze direction within our virtual worlds, measured as grossly as we measure it here, reflects actual observation of targets within that world. If this is the case, then the focus and distribution of gaze throughout the environment should correlate with better performance observing ongoing changes in The Panopticon. Second, we sought to rule out the influence of such basic cognitive abilities on any between-subjects differences in gaze and movement behavior observed in the other (affectively loaded) virtual worlds. If the effects of emotion regulation or fear are attributable to observational ability, then performance in The Panopticon score should positively correlate with these variables.

**2. General Methods**

The Virtual Reality Wunderkammer consists of four virtual worlds, all of which are described here: The Affect Gallery, The Crowded Room, Room 101, and The Panopticon. The Methods section is divided into a General section (this section) which provides the common details of participants and procedures, and subsequent sections which provide the unique details for each of the four paradigms including paradigm-specific methods and results.

**2.1. Participants**

In total, 324 participants participated in at least some portion of the study described here (191 women, ages 22 to 55, mean age 41). Of those, 319 completed The Affect Gallery, 324 completed the Crowded Room, 310 completed Room 101, and 324 completed the Panopticon. These participants were part of The ReSource Project, a large longitudinal study on mental training. For details about this project see ([Singer, Kok, Bornemann, Bolz, & Bochow, 2015](#_ENREF_88)). Participants in the ReSource Project were selected from a pool of approximately 4,700 applicants. Participants lived in or around the Leipzig and Berlin and, for the purposes of the larger study, were required have access to the internet, no recent episodes of mental illness, no recent use of medications that affect the central nervous, no history of drug or alcohol abuse, and no academic work in psychology ([Singer, et al., 2015](#_ENREF_88)). In addition to that initial screening for the larger project, participants were also screened when they entered the lab for the study reported here. During this screening, participants were asked if they were pregnant or had a history of epilepsy or stroke. No participants reported these conditions. All of the data presented here were measured at baseline of the ReSource Project, prior to training.

Participants provided informed consent for the experiment according to procedures approved by the Research Ethics Committee of the University of Leipzig with the number 376/12-ff, and the Research Ethics Committee of the Humboldt University in Berlin (Mathematisch-Naturwissenschaftliche Fakultät II), with the numbers 2013-02, 2013-29, and 2014-10.

**2.2. Materials**

All participants completed the Wunderkammer at the Virtual Reality Lab at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig, Germany. They completed questionnaires (i.e., the emotion regulation questionnaires) online ([Block & Kremen, 1996](#_ENREF_13); [Carver, et al., 1989](#_ENREF_19); [Garnefski, Kraaij, & Spinhoven, 2001](#_ENREF_33); [Loch, Hiller, & Witthoeft, 2011](#_ENREF_59)).

**2.2.1. Immersive virtual environments.** The four immersive virtual environments (IVEs) were programmed and rendered using Vizard 4.0. The 3D models, textures, and audio for these worlds were created using Autodesk 3DS Max, Photoshop, and Audacity, respectively. Each room was approximately 5 x 8 meters and 3.5 meters tall.

**2.2.2. Display devices**. The immersive virtual environments (IVEs) were rendered via an NVIS nVisor SX60 stereoscopic head-mounted display (HMD) with integrated Sennheiser® headphones. This HMD has a 44 degree horizontal field of view and 35 degree vertical field of view. Motion capture was done using a 10 camera Vicon MX3+ system and Vicon Tracker software. Markers on the HMD tracked the head and a custom-made bracelet marker was worn around the participant’s wrist to track the hand. Position and orientation of these markers was gathered with Vicon Tracker and streamed to Vizard 4.0 on the rendering computer. With this set-up, participants could walk around and look around the virtual worlds as they would walk and look around the physical world.

**2.2.3. Controller.** In two of the worlds (The Panopticon and The Affect Gallery), participants used a virtual laser pointer to complete the tasks. This virtual laser pointer was controlled by a physical pointer which participants used to select items in The Panopticon and to answer questions in The Affect Gallery. These tasks are described in greater detail below in each of those paradigms’ Methods sections.

**2.3. Procedure**

When participants arrived in the lab, they were first hooked up to physiological equipment and completed baseline physiological measures. Before the experiment began, participants were reminded that they could terminate the experiment at any point. They were also asked to report to the experimenter immediately if they felt dizzy or nauseated. Participants completed all four paradigms within the same experimental session in the following order: The Panopticon, The Crowded Room, The Affect Gallery, and Room 101. Experimenters checked with participants between each of the paradigms to make sure they were comfortable enough to continue. Participants heard instructions via audio recordings at the beginning of each of the different IVEs. Those instructions are described in each of the Procedure sections below.

**2.4. Measures**

**2.4.1. Motion capture.** The position and orientation of the participant’s head was recorded at approximately 17 Hz. Using these data, we calculated when targets fell within the field of view of the head-mounted display (i.e., when the targets were visible). In addition, we used the motion capture data to determine the distance between the participant and a given target. The calculations for paradigm-specific measures are described in the individual Measures sections below.

**2.4.2. Post-tasks questionnaire**. At the end of the experiment, participants completed a questionnaire regarding their experience in the Wunderkammer. These were important for our analyses of Room 101 (see Room 101 Methods for details).

**2.4.3. Emotion regulation factor**. The participants also completed a large set of questionnaires as part of the ReSource Project ([Singer, et al., 2015](#_ENREF_88)). These questionnaires were completed online at the participant’s convenience (although before the onset of the training portion of the ReSource Project). Here we use a factor derived from these questionnaires as our measurement of differences in the degree to which individuals engage in healthy emotion regulation strategies ([Singer, et al., 2015](#_ENREF_88)). This factor was derived by applying a principal components factor analysis (see ([Singer, et al., 2015](#_ENREF_88)) for details) to three questionnaires: the COPE ([Carver, et al., 1989](#_ENREF_19)), the CERQ ([Garnefski, et al., 2001](#_ENREF_33); [Loch, et al., 2011](#_ENREF_59)), and the ER-89 ([Block & Kremen, 1996](#_ENREF_13)). The first factor to fall out of this analysis, the “resilient” regulation factor, loaded high on ego resilience (ER-89), positive reappraisal (CERQ), active coping (COPE), planning (COPE and CERQ), and positive reinterpretation (COPE). For the loadings of the different questionnaires on this factor, see Table 1. Because this resilient regulation factor reflects a generally healthy set of emotion regulation strategies, we included it in our analyses to test whether or not the degree to which individuals employ resilient emotion regulation styles would moderate their gaze and movement behavior in the different virtual worlds of the Wunderkammer.

**2.4.4. Additional measures**. While participants were inside the IVEs we recorded heart rate, respiration, and skin conductance. Because these data are not directly relevant to the present manuscript, they are not reported here (but see McCall et al., in review).

**3. The Affect Gallery**

**3.1. Methods: The Affect Gallery**

**3.1.1. Materials: The Affect Gallery.** The Affect Gallery (Figure 2) was a square room with twelve picture frames, evenly distributed around the room. Within each of these frames was a slideshow that repeatedly cycled through a series of eight photographs. A given photo occupied the frame for 5 seconds and then was replaced by the next photo in the queue. The content of these slideshows varied in terms of both valence (positive versus negative) and arousal (low versus high) such that a given frame displayed photographs of a specific combination of these variables (e.g., a high arousal negative slideshow looped through highly arousing and negatively valenced photographs). The room was divided into quadrants such that the slideshows of a given combination of arousal and valence were all in the same quadrant. The placement of these quadrants in the room (e.g., the placement of the positive/high arousal slideshows in the northwest corner and etc.) was randomized between individuals.

The photographs within the slideshows were taken from three main sources: the International Affective Picture System ([Lang, Bradley, & Cuthbert, 2008](#_ENREF_58)), the Geneva Affective Picture database ([Dan-Glauser & Scherer, 2011](#_ENREF_23)), and the set used in Harris et al, 2011 ([Harris & Fiske, 2011](#_ENREF_42)). A set of pictures drawn from these sources were rated by observers in a pilot study (n = 124). Participants used an affect grid defined by valence and arousal to rate those images ([adapted fromRussell, Weiss, & Mendelsohn, 1989](#_ENREF_83)). We used these ratings to select the set of pictures that would appear in each quadrant of the Affect Gallery. In order to appear in a given quadrant, the majority of raters had to place that picture in the quadrant.

**3.1.2. Procedure: The Affect Gallery.** Participants were introduced to The Affect Galleryas a museum. Participants were first asked to walk a circle around the room so that they had a chance to see all the slideshows. This task was guided by a red frame that moved slowly around the room, stopping on each slideshow for ten seconds. Once they had completed this task, they were told that they could walk freely through the space, however they wanted to. This “free exploration” period (the critical portion of this paradigm) lasted for three minutes. After that period was over, participants were asked to rate the arousal and valence of each quadrant of the room by using the laser pointer and affect grids ([adapted fromRussell, et al., 1989](#_ENREF_83)) placed in each of the four quadrants of the room. The affect grids had two dimensions, one horizontal dimension representing valence and one vertical dimension representing arousal. Both dimensions spanned from -1 to 1. By selecting a point in this space, participants could rate the given quadrant of the room in terms of both its valence and its arousal.

**3.1.3. Measures: The Affect Gallery.** In the Affect Gallery, we calculated two behavioral variables: looking time and distance. Looking time was defined as the amount of time an individual spent looking at a given category of picture (i.e., positive high arousal, negative high arousal, positive low arousal, negative low arousal) during the free exploration period. To calculate this measure we went through every sample of the tracking data during the free exploration period and determined if a slideshow was in the field of view. If multiple slideshows fell in the field of view, we counted the slideshow closest to the center of the field of view. This process produced time counts for each of the four categories of slide show. For our distance measure, we calculated the minimum distance the participant came to a given category of slideshow (i.e., the minimum distance the came to any of the slideshows within that category).

**3.2. Results: The Affect Gallery**

As a validation check, we tested the post-task ratings of the quadrants of the Affect Gallery (the ratings provided on the affect grids). As expected, participants rated the negatively valenced quadrants as significantly negative in valence, the positive quadrants as significantly positive, the high arousal quadrants as high in arousal, and the low arousal quadrants as low in arousal (see Table 2 for means and statistical tests).

To test the effects of valence and arousal on looking behavior, we ran a repeated measures ANOVA with looking time as the dependent variable and valence, arousal, and their interaction as the predictors. We found a main effect of valence, F(1,318) = 74.0, p <.001, and no effect of arousal, F(1,318) = .78, p = .38. As predicted, participants spent more time looking at positively valenced images than negatively valenced images. We further found an interaction between valence and arousal, F(1,318) = 14.54, p < .001, that revealed that the effect of valence on looking behavior was stronger for the high arousal images. As Figure 2 illustrates, mean looking time for high arousal positive images was the highest whereas mean looking time for high arousal negative images was the lowest.

We ran the same ANOVA with looking distance as the dependent variable. Again we found an effect of valence, F(1,318) = 13.2, p < .001, but no effect of arousal, F(1,318) = .06, p = .81 nor of the interaction between valence and arousal, F(1,318) = .73, p = .39. As Figure 2 illustrates, participants came closer to positive versus negative images.

To test if individuals high in healthy emotion regulation exhibited different looking behaviors in The Affect Gallery, we ran a repeated measures ANCOVA with looking time as the dependent variable and valence, arousal, and their interaction as predictors. We included the resilient regulation factor as the covariate, allowing it to interact with valence, arousal, and their interaction. This analysis revealed a significant interaction between the resilience and valence, F(1,302) = 11.5, p < .001, whereby resilient regulators showed a more dramatic preference for positively versus negatively valenced images. The analysis also revealed a significant interaction between resilient regulation and arousal, F(1,302) = 8.79, p = .003, whereby high regulators showed a preference for high arousal images as compared to the opposite preference among individuals who were less resilient. We found no interaction between the resilient regulation factor and the interaction between arousal and valence, F(1,302) = .004, p = .95. Finally, we found an overall effect of resilient regulation whereby resilient regulators spent slightly less time looking at the slideshows in general, F(1,302) = 5.00, p = .03.

We repeated this ANCOVA, this time using distance as the dependent variable. Here we found no significant interaction between resilient regulation and valence, F(1,302) = 11.36, p = .99, although we did find a significant interaction between resilient regulation and arousal, F(1,302) = 10.31, p < .001 whereby highly resilient individuals came closer to high arousal as compared to low arousal images while less resilient individuals showed the opposite pattern. We found no interaction between resilient regulation and the interaction between valence and arousal, F(1,302) = .89, p = .35. Finally, we again found an overall effect of resilient regulation whereby resilient individuals stayed further away from the images, F(1,301) = 4.98, p = .03.

In summary, participants came closer to and spent more time looking at positive versus negative images. The valence bias in looking behavior was particularly strong for high arousal images and among individuals high in resilient emotion regulation tendencies.

**4. The Crowded Room**

**4.1. Methods: The Crowded Room**

**4.1.1. Materials: The Crowded Room.** The Crowded Room was a room in which participants encountered three different humanoid agents (Figure 3) while completing an ostensible memory task. Each of these agents displayed a different emotion: sad, neutral, or angry. Animations were based roughly on prototypical displays of emotion ([Ekman & Rosenberg, 1997](#_ENREF_27); [Kappesser & de C Williams, 2002](#_ENREF_55)). The angry agent had a lowered brow, tightened eyelids, a raised upper lip and was making a fist. The sad agent had raised inner eyebrows, the corners of his mouth were lowered and he was slightly hunched over. The neutral agent displayed no particular affect. Importantly, each of these three agents were animated to “watch” the participants as they passed, following the participants with their gaze.

To avoid differences introduced by target gender, we included only male agents. Each agent looked like a different person but the emotional displays of the agents were counterbalanced such that the sequence of agents’ displays was randomized between participants. The Crowded Room also included three “bystanders”, one male and two female, as well as several pictures placed around the room. These other objects were added so that participants had more to examine if the room in case they chose not to look at the target agents.

**4.1.2. Procedure: The Crowded Room.** The task in the Crowded Room is adapted from Bailenson et al., ([Bailenson, 2003](#_ENREF_7)). When participants first entered the room, they were asked to stand on a red square in one corner of the room. They were then told that they would be completing a memory task with several rounds. During each round, the lights would first go out, then turn back on again, at which point an individual would appear in the middle of the room. The participants’ goal was to walk around the individual, look at a number on his back, walk back to the red square and report the number they remembered seeing. After receiving these instructions, the participants completed a practice round and were given the opportunity to ask questions about the task. Once all questions were answered and the task was clear, the participants proceeded to complete the task three times, once for each target agent. The order and identity of the agents was counterbalanced between participants.

**4.1.3. Measures: The Crowded Room.** For our behavioral analysis in the crowded room, we looked at how both interpersonal distance and interpersonal gaze were affected by agent (i.e., the neutral, sad, and angry agents). Our measure of distance was the minimum distance participants came to each of the agents while completing the task ([Bailenson, 2003](#_ENREF_7); [McCall, et al., 2009](#_ENREF_66)). To measure gaze, we calculated the angular distance from looking directly at the agent’s face for each sample ([McCall, et al., 2009](#_ENREF_66)) and then took the average of these values for each trial.

**4.2. Results: The Crowded Room.**

To test the effects of agent emotion on interpersonal distance, we ran a repeated measures ANOVA with agent emotion as the independent variable and minimum distance as the dependent variable. This analysis revealed a significant effect of agent emotion, F(2,323) = 3.9, p = .02. Pairwise comparisons revealed that participants avoided the angry as compared to the neutral, Mdiff = .015, p = .03, and sad, Mdiff = .018, p = .008, agents.

We repeated this ANOVA, but with angular distance as the dependent variable. This analysis revealed a significant effect of agent emotion, F(2,323) = 13.4, p <.001. Pairwise comparisons revealed that participants directed their gaze most closely towards the angry, Mdiff = 1.56, p < .001, and sad agents, Mdiff = 1.17, p <.001, when compared to the neutral agent. There was no significant difference in angular distance between the sad and angry agents, Mdiff = .38, p = .23.

To test for a relationship between emotional resilience and interpersonal distancing behavior, we ran a repeated measures ANCOVA with the resilient regulation factor as a covariate. We found no significant interaction between agent emotion and resilient regulation, F(2, 306) = 2.86, p = .78, nor did we find a main effect of resilience, F(1,307) = .49, p = .49. We repeated this same ANCOVA, using angular gaze distance as the dependent variable. Again we found no interaction between resilient regulation and agent emotion, F(2,306) = .40, p = .67. We did, however, find a main effect of resilient regulation on gaze, F(1,307) = 4.77, p = .03, whereby resilient regulators gazed more directly at the agents.

In summary, participants gazed more directly at the angry and sad agents than the emotionally neutral agent. In terms of interpersonal distance, however, participants avoided the angry as compared to the other two agents. None of the effects of agent emotion were moderated by individual differences in resilient emotion regulation tendencies.

**5. Room 101**

**5.1. Methods: Room 101**

**5.1.1. Materials: Room 101.** Room 101 (Figure 4; see also McCall et al, in review) was a dimly lit room with a relatively ominous ambient humming noise. Over the course of five minutes, the room evolved through a series of epochs: 1) the room began empty, 2) several crates exploded, 3) spiders covered the walls and surfaces of the room, 4) the room was empty again, 5) the sound of footsteps followed the participant before gunshots exploded and blood splattered over the walls, 6) the floor of the room collapsed, revealing a 3.5 meter drop to the ground, 7) the room was empty but for a giant spider, 8) the room was empty again. For most of data presented here, participants experienced the version of Room 101 as just described. However, participants who reported a phobia for heights or spiders at the beginning of the experiment had slightly different versions; participants who reported a phobia for spiders encountered snakes and participants who reported a phobia for heights saw no significant drop with the floor collapsed.

**5.1.2. Procedure: Room 101.** The participant’s task during Room 101 was to find and grab glowing jars as they appeared around the room. To grab a jar, participants simply touched it with their virtual hand and, at that point, the jar disappeared. The jars appeared serially such that one jar would appear immediately after the participant had grabbed the last jar. When a jar appeared it was initially red and then turned green after approximately 3 seconds. The participant could not grab a jar until it turned green (a feature that discouraged participants from moving so quickly through the world that they missed the various stimuli). This task served the purpose of giving participants a goal that would direct them around the world. Participants were not encouraged to grab a particular number of jars nor were they rewarded for doing so.

**5.1.2. Measures: Room 101.** Our behavioral measures in Room 101 were velocity of movement through the room and the degree to which participants looked around the room. Because different epochs of Room 101 introduce different obstacles to walking (i.e., the spiders versus the collapsed floor versus the empty room), velocity varied significantly between epochs. To make velocity measures comparable across epochs, we calculated mean velocity per epoch and z-scored the velocity across participants within each epoch.

To measure the degree to which participants looked around the room, we calculated the angular velocity of the head during each epoch of Room 101. As with velocity, we z-scored this value across participants for each epoch.

We measured fear in Room 101 with a question in the post-task questionnaire. Participants used a seven point scale ranging from “I disagree” to “I agree strongly” (“Stimme nicht zu” to “Stimme sehr zu) to endorse the statement, “I found this virtual world [Room 101] very frightening” (“Ich fand diesen virtuellen Raum sehr unheimlich”).

**5.2. Results: Room 101**

The mean fear ratings for Room 101 were 4.46 (SD = 1.83) out of 7. To test if this fear reduced participants’ walking velocity in Room 101, we ran linear mixed effects model with z-scored velocity at each epoch as the target variable. We entered epoch, fear and the interaction between them as the fixed variables. To account for within subject dependency, we entered intercept as a subject level random effect. This model revealed significant fixed effects of fear, F(1, 2448)= 12.96, p < .001; the more frightening the participants found Room 101, the slower they walked (Figure 4). The model also revealed a significant interaction between fear and epoch, F(7, 2448) = 2.28, p = .03. As Figure 4 illustrates, fear had a particularly strong effect on velocity during the epochs when more threatening events occurred such as when the spiders were present in the room or when the floor collapsed.

To test if fear also reduced the degree to which participants moved their heads around during Room 101 (i.e., the degree to which they looked around the room), we ran another mixed model with angular velocity as the target variable. Again we entered epoch, fear and the interaction between them as fixed variables. Because people naturally rotate their head when they are walking in a circle around a room, we controlled for walking velocity by including it as an additional fixed effect. Indeed, the model revealed this relationship via a significant effect of velocity, F(1, 2447) = 120, p < .001, whereby the faster people walked the more they moved their head. This model also revealed significant effects of fear, F(1, 2447)= 10.65, p < .001; the more frightened participants found Room 101 the less they looked around the room. This model further revealed an interaction between fear and epoch, F(1,2447) = 2.28, p = .03, whereby frightened individuals restrained their head movement progressively more over the course of the experience, see Figure 4.

To test if healthy emotion regulators experienced less fear in Room 101, we calculated the correlation between the resilient emotion regulation factor and self-reported fear in Room 101. This relationship was not significant r(302) = -.07, p = .25.

To test for the influence of resilient emotion regulation on velocity, we ran another linear mixed model with z-scored velocity at each epoch as the target variable. We entered epoch, fear, the resilient regulation factor and all possible interactions between resilient regulation and the other factors as fixed factors. As always, we entered intercept as a subject level random effect. This model revealed both a main effect of resilient regulation, F(1, 2326) = 4.57, p = .03, and an interaction between resilient regulation and fear, F(1,2326) = 4.96, p = .03. In general resilient regulators walked more quickly through the world. However, they were also more strongly affected by fear. As Figure 4 illustrates, highly resilient regulators showed a more dramatic decrease in velocity when they were afraid. We found no three-way interaction between resilience, fear and epoch, F(2,2326) = .58, p = .78.

To test for the influence of resilient regulation on gazing about the room, we repeated the previous mixed model with angular velocity as the target variable and adding walking velocity to control for its incidental effect on angular velocity. This model revealed no main effect of resilient regulation, F(1,2325) = 2.46, p = .12, no interaction between resilient regulation and fear, F(1,2325) = 1.7, p = .19, and no interaction between regulation, fear and epoch, F(1,2325) = 1.13, p = .34.

In summary, participants who reported being afraid in Room 101 moved more slowly through the world and looked less around the world, particularly during the more disturbing epochs. Participants who were high in resilient emotion regulation tendencies were more likely to slow down if they were frightened by the world.

**6. The Panopticon**

**6.1. Methods: The Panopticon**

**6.1.1. Materials: The Panopticon.** The Panopticon was originally designed to measure visual detection in a complex, three-dimensional environment. Specifically, it measures participants’ ability to detect changes in the surrounding environment. While inside the Panopticon, participants sat on a rotating stool with their back against one wall of the virtual room such that by turning their head, they could see the other three walls of the room in their entirety. On those three walls were two rows of framed pictures and one row of sconces. Each wall was also split up into two segments, each with its own wallpaper. Together there were a total of 24 pictures, 24 frames, 6 wall segments, and 6 sconces. The pictures, frame, and wall segments all had the ability to gradually change color (henceforth, “colored objects”) while the sconces had the ability gradually morph between shapes (henceforth, “morphable objects”). During the critical task in the Panopticon, half of the objects changed while the other half did not.

All colored objects had two endpoint colors, randomly chosen from blue, green, and red. At the beginning of the task, their color was randomly chosen somewhere in between these endpoints, i.e. somewhere on the linear trajectory between the two endpoints’ RBG values. Statically colored objects stayed at this beginning point while dynamically changing colored objects oscillated back and forth between their color endpoints over the course of the task. Every possible combination of changing versus static wall segment, changing versus static frame, and changing versus static picture was used for each participant although the placement of each combination varied randomly.

Morphable objects also had two endpoints, randomly chosen from three possible morphs. At the beginning of the task, each morphable object was set at a randomly chosen morph state somewhere between their endpoints. Static morphable objects remained at this point while dynamic objects oscillated between their two endpoints for the duration of the task. .

For all of the dynamic objects, the rate of change was between .4 Hz and .02 Hz (between 2.5 and 50 seconds per cycle). However, these dynamic objects only changed while they were in view. This was done so that participants could not employ a memory strategy whereby they could turn their head away from an object, commit the old color or shape to memory, and then turn back to see if it had changed from the remembered state.

During the task the participant used a virtual laser pointer. The direction of the virtual laser was linked to their hand so that they could point to at any object in the room. The participant also held the controller. By pressing a button on the controller they could select the object at which they were pointing. When an object was selected it was covered in dots. Participants could deselect an object by pointing on it and clicking again.

**6.1.2. Procedure: The Panopticon.** At the beginning of the Panopticon, participants were told that half of the objects in the room, including the pictures, picture frames, sconces, and wall segments, would be changing color or changing shape. Their task was to use the laser pointer to select objects that were changing. Participants were then given the opportunity to look around the room and select each type of object. After that, they completed one-minute practice rounds, receiving feedback when the selected an object. After the practice round, the experimenter asked the participant a series of questions to determine if they understood the instructions. If they did not, the experimenter went back over the instructions and the participant completed the practice task again. Once the participant was ready, the task began. Participants had three minutes to identify as many changing objects as possible.

**6.1.3. Measures: The Panopticon.** Performance in the Panopticon was measured with d-prime ([Macmillan & Creelman, 2004](#_ENREF_61)) using hits (changing targets marked by the participant), misses (changing targets not marked by the participant), false alarms (unchanging targets marked by the participant) and correct rejections (unchanging targets not marked by the participant).

We calculated two gaze-related variables for The Panopticon: the *fixation duration* of gaze and *spatial focus*, the degree to which those fixations were focused on a few targets versus spread throughout the environment space. To derive these variables, we first calculated the longest stretch of time that each target was visible in the participant’s view frustum. To estimate fixation duration, we took the mean of those per-target values. As such, higher values reflect longer fixation durations on targets. To estimate spatial focus, we calculated the coefficient of variation (CV) across those per-target values. Higher values reflect more singular focus while lower values reflect more evenly spread focus on targets around the entire space. We used the CV instead of the standard deviation because it accounts for the magnitude of the mean (*CV = SD/mean*). Given the nature of the task, fixation duration and spatial focus should improve performance as the participant both needs to focus on targets for several seconds to detect change but must also look around the room to indentify multiple changing targets.

**6.2. Results: The Panopticon**

For our first analysis with the Panopticon data, we sought to rule out the possibility that effects of resilient emotion regulation (as observed in the Affect Gallery and Room 101) were a consequence not of differences in emotion regulation per se, but of more global differences in observational ability. To test this possibility, we calculated the correlation between the resilient emotion regulation factor and the observation performance (d-prime) from The Panopticon. This correlation was not significant, r(308) =-.003 , p =.96. Along similar lines, we also wanted to rule out the possibility that the self-reported fear variable from Room 101 was attributable to better observational ability. Again, we found no significant correlation between fear and the d-prime from The Panopticon r(316) =.01, p = .81. Together these analyses suggest that abovementioned effects of individual differences in the emotion regulation factor (in The Affect Gallery and Room 101) and fear (in Room 101) were not the product of greater visual detection ability.

Finally, we used the behavioral data from The Panopticon to validate our assumption that gaze direction in the virtual worlds corresponds with actual attention to targets in a world. If this is the case, then both long fixation durations (i.e., observing long enough to detect changes in individual targets) and an low spatial focus (i.e., spreading observation throughout the room) should predict better performance in The Panopticon. To test this hypothesis we ran a linear regression with d-prime as the dependent variable. We entered fixation duration and spatial focus as the independent variables. This regression was significant, R2 = .35, F(2,323) = 22.09, p < .001. Moreover, both fixation duration, β = .360, t(323) = 41.48, p < .001, and spatial focus, β = -.11, t(323) = -2.10, p = .04, accounted for variance in performance in the predicted direction.

**7. Discussion**

In the current study we used the Wunderkammer, a new set of virtual worlds, to study the differential effects of distinct emotional contexts on unconstrained gaze and movement. We used these naturalistic environments to better understand how individuals spontaneously choose to move through and explore their environments when freely allowed to do so. In each of three virtual worlds, we manipulated affective content in a different way. In The Affect Gallery we manipulated the valence and arousal of inanimate objects via images within an art museum. In The Crowded Room, we manipulated the emotional expressions of other people (i.e., agents) in the environment. In Room 101, we manipulated the threatening nature of the entire environment. Within all of these worlds, we measured how these different environmental features influenced participants’ spontaneous and naturalistic use of gaze and movement.

Our results revealed that the different worlds within the Wunderkammer reliably influenced gaze and movement. As expected, participants physically avoided and looked away from the negative images within The Affect Gallery while showing more approach and gaze toward the positive images. This basic hedonic preference was particularly strong for the more arousing images, suggesting that the preferential processing of arousing images “amplified” the effects of valence. Interestingly and in contrast to these findings, participants showed no such bias against negativity in The Crowded Room. As predicted, they looked more at the faces of agents expressing negatively (as compared to neutrally) valenced emotions. Moreover, physical avoidance within this social context was not driven by the negative valence of the agents’ expressed emotions, per se, but by the specific nature of the emotion; participants physically avoided the angry agents as compared to the neutral and sad agents, likely in response to the threatening nature of that angry emotional display. In the more pervasively threatening Room 101, we observed yet another pattern of eye-gaze and movement in response to negative stimuli. Subjectively frightened individuals slowed or stopped moving, particularly during the most dramatic portions of the experience. Fear also reduced mobility in the degree to which participants looked around the room, particularly during epochs in which there was a single frightening target (i.e., a monstrous spider or a collapsed floor) upon which to focus one’s attention. This pattern of results demonstrates clearly how responses to emotionally valenced stimuli do not represent a unitary class of fixed response but vary as a function of the specific context ([Barrett, et al., 2011](#_ENREF_9); [Gendron & Barrett, 2009](#_ENREF_34)).

Further analyses revealed that individual differences in resilient emotion regulation also played an important role in moderating some of these behavioral effects. As our measure of resilient emotion regulation, we used a data-driven factor comprised of several healthy regulation styles as well as general emotional resilience ([Singer, et al., 2015](#_ENREF_88)). Individuals who were high in this factor were more strongly influenced by the valence of images in the art gallery, showing a stronger preference for gazing at positive versus negative images. These findings are in line with the notion that active regulation of emotion can involve strategically orienting one’s gaze to positive versus negative features of the environment (e.g., [J. Gross, 1998](#_ENREF_37); [Isaacowitz, 2006](#_ENREF_46)). Interestingly, participants high in this resilient emotion regulation factor were just as frightened as other participants by Room 101. Their emotion regulation strategies apparently didn’t reduce fear in that unpredictable and pervasively threatening environment. Importantly, however, those high in the regulation factor were more likely to modulate their behavior based on that fear, moving more quickly when they were not afraid and slowing down more dramatically when they were. Together with the within-subjects findings, this pattern of results clearly illustrates the importance of taking into account both the specific context and the individual’s predispositions when making predictions about behavioral responses elicited by emotional stimuli in the environment. Traditional laboratory experiments on affect or emotion that present words of pictures ([e.g., photos of sad, angry or fearful faces, for review see Quigley, et al., 2014](#_ENREF_79)), might fail to reveal such complex patterns. Here we do so with different ecologically and emotionally valenced virtual environments that unfold over time.

Several of these findings merit deeper discussion. For one, findings from The Affect Gallery illustrate the benefits of allowing participants to freely explore an environment without any explicit task instructions to direct them. This work expands upon research on studying motivated gaze toward 2D images ([Isaacowitz & Harris, 2014](#_ENREF_47); [Isaacowitz, et al., 2008](#_ENREF_49); [Isaacowitz, et al., 2006](#_ENREF_51)) and on situation selection during the exploration of physical ([Rovenpor, et al., 2013](#_ENREF_81)) and virtual ([Rinck, et al., 2015](#_ENREF_80)) environments. Whereas those prior studies looked at the effect of valence or threat on exploration, here we tested a novel hypothesis by also examining the effects of arousing stimuli. We had reasoned that since arousing targets capture attention and facilitate processing ([e.g., Mather & Sutherland, 2011](#_ENREF_64)), participants would more quickly process the valence of highly arousing images and would, in turn, show a more dramatic effect of valence. This is indeed what they did. Critically, the free exploration nature of the paradigm allowed us to go beyond studying only initial attentional biases toward arousing images ([Anderson, 2005](#_ENREF_4); [Arnell, et al., 2007](#_ENREF_5); [Keil & Ihssen, 2004](#_ENREF_56); [Lundqvist, et al., 2014](#_ENREF_60)). Instead, we were able to see what happens in the moments after attention has been captured, when the individual can use that arousal-facilitated processing to further determine behavior. Research using free exploration could further examine trait- or state-based preferences for high versus low arousal images. It seems likely that arousal-based gaze preferences would correspond with general personality traits such as excitement-seeking or tranquility-seeking. Oddly, we found a preference for high arousal images among our resilient emotion regulators. We did not predict this pattern and can only speculate that people who know that they are able to regulate their emotions effectively may thus be in a position to freely expose themselves to highly arousing stimuli. Further research should investigate the role of arousal in strategic gaze selection and its interaction with individual traits.

The pattern of behavior observed in The Crowded Room illustrate that interactive agents have uniquely social effects on participants’ behavior as compared to emotionally valenced objects or environments (e.g., [Bailenson, 2003](#_ENREF_7); [Blascovich & Bailenson, 2011](#_ENREF_11)). Participants gazed more at the negatively emoting agents, but avoided only the angry one, revealing that even in a minimally interactive context social behavior goes beyond hedonic goals and that social vigilance and social approach are independent of one other. Based on the logic that people who tend to actively regulate their emotions might avoid looking at negatively valenced facial expressions ([see Isaacowitz, et al., 2008 for a related argument](#_ENREF_49)), we had expected the emotion regulation factor to predict avoidance in gaze and interpersonal distance from the sad and angry agents. We found no such effect. While the present research differs in many ways from existing research on emotion regulation and attention to faces ([Isaacowitz, et al., 2008](#_ENREF_49)), one particularly critical difference is that we used interactive agents, and not photographs, to study social gaze. Research on attention to faces illustrates that patterns in attention to photographed faces may have no bearing on attention to faces in the real world ([Foulsham, Walker, & Kingstone, 2011](#_ENREF_29)). Given that, future research on the role of emotion regulation in social gaze should pursue the question of whether interactive, socially “present” agents elicit different responses than mere photographs or videos of faces (see also[Aviezer et al., 2015](#_ENREF_6); [Barrett, et al., 2011](#_ENREF_9); [Schilbach, 2015](#_ENREF_85)).

Finally, Room 101 allowed us to take a unique look at responses elicited by being exposed to an unpredictable and threatening environment for a sustained (i.e., 5 minute) period. This allowed us to investigate the hypothesis that freezing and tonic immobility may be the prepotent response to such environments. Little research has been done on this topic in humans (but see [Sagliano, et al., 2014](#_ENREF_84); [Schmidt, et al., 2008](#_ENREF_87)) for the obvious reason that it is very difficult to create an ongoing, physically threatening situation in an experimental setting. Filling one’s laboratory with hundreds of spiders, explosions, blood, gunshots, and a collapsing floor would be difficult to fund and likely unpopular with custodial staff and neighboring labs. Here virtual reality allowed us to do so. We created a frightening environment that was unpredictable and filled with pervasive threats. As predicted from the research on the behavioral cascade in animals from freezing to tonic immobility ([Bracha, 2004](#_ENREF_14)), frightened people were less mobile. Whether this change in mobility reflects freezing, tonic immobility, or a combination of the two is unclear. What is clear, however, is that the current paradigm can help us understand how the very basic and evolutionarily ancient behavioral cascade plays out in humans.

Our results suggest that active regulation strategies (e.g., reappraisal, positive refocusing) did not help reduce the experience of fear in Room 101. Nevertheless, active regulators were more likely to slow their behavior when they were afraid. The mechanism underlying this pattern is not clear. It is possible that the more actively an individual regulates their emotions, the more actively they modulate all of their behavioral responses to threat. If this is the case, then resilience may not only be a matter of regulating responses but of responding appropriately to the environment and changes therein. Future research could uniquely address this question with paradigms like Room 101.

Before concluding, we should address some shortcomings of the present study. For one thing, we have made many arguments about the relationship between emotion regulation and behavior. To be clear, we did not manipulate emotion regulation directly in this study. Instead, we used individual differences in the degree to which people report using active regulation strategies and being resilient. Given that, the reported relationships between resilient emotion regulation and behavior are correlational and do not necessarily imply causation. For example, one could argue that the demonstrated effects of resilient regulation are not a consequence of resilience or emotion regulation per se, but of the fact that people who are high in emotion regulation ability are also generally stronger in executive functioning (e.g., [Hofmann, Schmeichel, & Baddeley, 2012](#_ENREF_45); [Pessoa, 2008](#_ENREF_78)). Because of differences in cognitive capacity, these individuals may have been more observant of the affective changes in the worlds and, as a consequence, more affected by them. However, evidence from The Panopticon argues against this point. The Panopticon measured the ability to detect visual changes in complex, three dimensional environments. Scores on this ability had no relationship to our resilience factor. Given that fact, the demonstrated effects of resilience cannot easily be attributed to more general differences in participants’ ability to process features of in the environments. The more likely explanation is that dispositional differences in the ways one handles emotions manifest at a micro-level, in the simple behaviors one uses when exploring and walking through an environment. More research is necessary, however, to test this causal pathway.

A second shortcoming of the current study is the relative lack of precision in the gaze data. Unlike eye tracking research (e.g., [Henderson, 2003](#_ENREF_44); [Isaacowitz & Harris, 2014](#_ENREF_47)) our measures of gaze depended upon on head movement or the contents of the field of view and did not look at foveal movement at all. Nevertheless, gross approximations of gaze showed clear relationships to actual performance in The Panopticon, suggesting that our measures were sufficiently interpretable. Moreover, the fact that we found meaningful patterns in gaze based on these relatively gross measures suggests that future work using more precise eye tracking within virtual environments will be all that much more powerful at examining the effects of affect on free gaze selection.

The data presented here have practical implications. If industry predictions are to be believed ([Fowler & Stern, 2015](#_ENREF_30); [Nicas, 2016](#_ENREF_71); [Wingfield, 2015](#_ENREF_91)), virtual reality will increasingly become part of our lives via gaming and other forms of entertainment as well as in the arts, design, and education. This trend will provide abundant opportunities to measure users’ gaze and movement as they explore their digital environments. Such data might prove useful in implicitly detecting users’ preferences (as in the Affect Gallery), their responses to other people (as in the Crowded Room), and their emotional state (as in Room 101). In this sense, these technologies can reap a wealth of information about the affective quality of user experience without relying upon explicit probes or questionnaires. Given that we can track movement and gaze of individuals in everyday environments (and outside of virtual reality), these benefits would furthermore extend to the physical world.

The goal of psychology is not to understand how people behave in a laboratory but to understand how people behave in the real world. Accordingly, ethological approaches to psychology have long championed the observation of behavior as it spontaneously unfolds within naturalistic contexts ([Kingstone, et al., 2008](#_ENREF_57)). Here we attempted such an approach within the laboratory by using immersive virtual environments. The results from our Wunderkammer reveal that naturalistic, emotionally complex virtual worlds go beyond traditional paradigms to capture the influences of context, time, and individual dispositions on behavior. This study provides evidence that virtual reality can help us better understand how affect shapes behavior in everyday life.

**Works cited**

Adolphs, R. (1999). Social cognition and the human brain. *Trends Cogn Sci, 3*(12), 469-479.

Albarracin, D., Johnson, B. T., & Zanna, M. P. (2014). *The handbook of attitudes*: Psychology Press.

Ambady, N., & Rosenthal, R. (1992). Thin slices of expressive behavior as predictors of interpersonal consequences: A meta-analysis. *Psychological Bulletin, 111*(2), 256.

Anderson, A. K. (2005). Affective influences on the attentional dynamics supporting awareness. *Journal of Experimental Psychology: General, 134*(2), 258.

Arnell, K. M., Killman, K. V., & Fijavz, D. (2007). Blinded by emotion: target misses follow attention capture by arousing distractors in RSVP. *Emotion, 7*(3), 465.

Aviezer, H., Messinger, D. S., Zangvil, S., Mattson, W. I., Gangi, D. N., & Todorov, A. (2015). Thrill of Victory or Agony of Defeat? Perceivers Fail to Utilize Information in Facial Movements.

Bailenson, J. N., Blascovich, J., Beall, A. C., & Loomis, J. M. . (2003). Interpersonal distance in immersive virtual environments. *Personality and Social Psychology Bulletin, 29*, 819–834.

Baron-Cohen, S., Lombardo, M., Tager-Flusberg, H., & Cohen, D. (2013). *Understanding Other Minds: Perspectives from developmental social neuroscience*: Oxford University Press.

Barrett, L. F., Mesquita, B., & Gendron, M. (2011). Context in emotion perception. *Current Directions in Psychological Science, 20*(5), 286-290.

Batty, M., & Taylor, M. J. (2003). Early processing of the six basic facial emotional expressions. *Cognitive Brain Research, 17*(3), 613-620.

Blascovich, J., & Bailenson, J. (2011). *Infinite reality: Avatars, eternal life, new worlds, and the dawn of the virtual revolution*: William Morrow & Co.

Blascovich, J., Loomis, J., Beall, A. C., Swinth, K. R., Hoyt, C. L., & Bailenson, J. N. (2002). Immersive virtual environment technology as a methodological tool for social psychology. *Psychological Inquiry, 13*(2), 103-124.

Block, J., & Kremen, A. M. (1996). IQ and ego-resiliency: conceptual and empirical connections and separateness. *Journal of Personality and Social Psychology, 70*(2), 349.

Bracha, H. S. (2004). Freeze, flight, fight, fright, faint: Adaptationist perspectives on the acute stress response spectrum. *CNS spectrums, 9*(9), 679-685.

Bradley, M. M., Costa, V. D., & Lang, P. J. (2015). Selective looking at natural scenes: Hedonic content and gender. *International Journal of Psychophysiology, 98*(1), 54-58.

Bradley, M. M., & Lang, P. J. (1994). Measuring emotion: the Self-Assessment Manikin and the Semantic Differential. *Journal of Behavior Therapy and Experimental Psychiatry, 25*(1), 49-59.

Brosch, T., Sander, D., Pourtois, G., & Scherer, K. R. (2008). Beyond fear rapid spatial orienting toward positive emotional stimuli. *Psychological Science, 19*(4), 362-370.

Cannon, W. (1929). *Bodily Changes in Pain, Hunger, Fear and Rage An Account of Recent Research Into the Function of Emotional Excitement* (2 ed.). New York: Apple-Century-Crofts.

Carver, C. S., Scheier, M. F., & Weintraub, J. K. (1989). Assessing coping strategies: a theoretically based approach. *Journal of Personality and Social Psychology, 56*(2), 267.

Chen, M., & Bargh, J. A. (1999). Consequences of automatic evaluation: Immediate behavioral predispositions to approach or avoid the stimulus. *Personality and Social Psychology Bulletin, 25*(2), 215-224.

Chisholm, J. D., Chapman, C. S., Amm, M., Bischof, W. F., Smilek, D., & Kingstone, A. (2014). A Cognitive Ethology Study of First-and Third-Person Perspectives. *PLoS ONE, 9*(3), e92696.

Conner, T. S., Tennen, H., Fleeson, W., & Barrett, L. F. (2009). Experience sampling methods: A modern idiographic approach to personality research. *Social and personality psychology compass, 3*(3), 292-313.

Dan-Glauser, E. S., & Scherer, K. R. (2011). The Geneva affective picture database (GAPED): a new 730-picture database focusing on valence and normative significance. *Behavior research methods, 43*(2), 468-477.

Darwin, C. (1965). The expression of the emotions in man and animals (1872). *Chicago: U of Chicago P*.

Dotsch, R., & Wigboldus, D. H. (2008). Virtual prejudice. *Journal of experimental social psychology, 44*(4), 1194-1198.

Eagly, A. H., & Chaiken, S. (1993). *The psychology of attitudes*: Harcourt Brace Jovanovich College Publishers.

Ekman, P., & Rosenberg, E. L. (1997). *What the face reveals: Basic and applied studies of spontaneous expression using the Facial Action Coding System (FACS)*: Oxford University Press.

Fiske, S. T., & Taylor, S. E. (2013). *Social cognition: From brains to culture*: Sage.

Foulsham, T., Walker, E., & Kingstone, A. (2011). The where, what and when of gaze allocation in the lab and the natural environment. *Vision research, 51*(17), 1920-1931.

Fowler, G., & Stern, J. (2015, December 27, 2015). The Tech That Will Change Your Life in 2016, *The Wall Street Journal*.

Fox, J., Arena, D., & Bailenson, J. N. (2009). Virtual reality. *Journal of Media Psychology: Theories, Methods, and Applications, 21*(3), 95-113.

Gallup Jr, G. G. (1974). Animal hypnosis: factual status of a fictional concept. *Psychological Bulletin, 81*(11), 836.

Garnefski, N., Kraaij, V., & Spinhoven, P. (2001). Negative life events, cognitive emotion regulation and emotional problems. *Personality and Individual differences, 30*(8), 1311-1327.

Gendron, M., & Barrett, L. F. (2009). Reconstructing the past: A century of ideas about emotion in psychology. *Emotion review, 1*(4), 316-339.

Gray, J. A. (1987). *The psychology of fear and stress* (Vol. 5): Cambridge Univ Pr.

Green, M. J., & Phillips, M. L. (2004). Social threat perception and the evolution of paranoia. *Neuroscience & Biobehavioral Reviews, 28*(3), 333-342.

Gross, J. (1998). The emerging field of emotion regulation: An integrative review. *Review of General Psychology, 2* (3), 271-299.

Gross, J. J. (2001). Emotion regulation in adulthood: Timing is everything. *Current-Directions-in-Psychological-Science, 10*(6), 214-219.

Gross, J. J. (2015). Emotion regulation: Current status and future prospects. *Psychological Inquiry, 26*(1), 1-26.

Gross, J. J., & Thompson, R. A. (2007). Emotion regulation: Conceptual foundations.

Hansen, C. H., & Hansen, R. D. (1988). Finding the face in the crowd: an anger superiority effect. *Journal of Personality and Social Psychology, 54*(6), 917.

Harris, L. T., & Fiske, S. T. (2011). Dehumanized perception: A psychological means to facilitate atrocities, torture, and genocide? *Zeitschrift für Psychologie/Journal of Psychology, 219*(3), 175.

Heider, F., & Simmel, M. (1944). An experimental study of apparent behavior. *The American Journal of Psychology*, 243-259.

Henderson, J. M. (2003). Human gaze control during real-world scene perception. *Trends in cognitive sciences, 7*(11), 498-504.

Hofmann, W., Schmeichel, B. J., & Baddeley, A. D. (2012). Executive functions and self-regulation. *Trends in cognitive sciences, 16*(3), 174-180.

Isaacowitz, D. M. (2006). Motivated gaze the view from the gazer. *Current Directions in Psychological Science, 15*(2), 68-72.

Isaacowitz, D. M., & Harris, J. A. (2014). Middle-aged adults facing skin cancer information: Fixation, mood, and behavior. *Psychology and aging, 29*(2), 342.

Isaacowitz, D. M., & Stanley, J. T. (2011). Bringing an ecological perspective to the study of aging and recognition of emotional facial expressions: Past, current, and future methods. *Journal of Nonverbal Behavior, 35*(4), 261-278.

Isaacowitz, D. M., Toner, K., Goren, D., & Wilson, H. R. (2008). Looking while unhappy mood-congruent gaze in young adults, positive gaze in older adults. *Psychological Science, 19*(9), 848-853.

Isaacowitz, D. M., Toner, K., & Neupert, S. D. (2009). Use of gaze for real-time mood regulation: effects of age and attentional functioning. *Psychology and aging, 24*(4), 989.

Isaacowitz, D. M., Wadlinger, H. A., Goren, D., & Wilson, H. R. (2006). Selective preference in visual fixation away from negative images in old age? An eye-tracking study. *Psychology and aging, 21*(1), 40.

James, L. K., Lin, C.-Y., Steed, A., Swapp, D., & Slater, M. (2003). Social anxiety in virtual environments: Results of a pilot study. *Cyberpsychology & behavior, 6*(3), 237-243.

James, W. (2011). *The Principles of Psychology (Volume 2 of 2)*: Digireads. com Publishing.

Kane, H. S., McCall, C., Collins, N. L., & Blascovich, J. (2012). Mere presence is not enough: Responsive support in a virtual world. *Journal of experimental social psychology, 48*(1), 37-44.

Kappesser, J., & de C Williams, A. C. (2002). Pain and negative emotions in the face: judgements by health care professionals. *Pain, 99*(1), 197-206.

Keil, A., & Ihssen, N. (2004). Identification facilitation for emotionally arousing verbs during the attentional blink. *Emotion, 4*(1), 23.

Kingstone, A., Smilek, D., & Eastwood, J. D. (2008). Cognitive ethology: A new approach for studying human cognition. *British Journal of Psychology, 99*(3), 317-340.

Lang, P. J., Bradley, M. M., & Cuthbert, B. (2008). International affective picture system (IAPS): Affective ratings of pictures and instruction manua. Gainesville, FL: University of Florida.

Loch, N., Hiller, W., & Witthoeft, M. (2011). Der cognitive emotion regulation questionnaire (CERQ) *Zeitschrift für Klinische Psychologie und Psychotherapie* (Vol. 40(2), pp. 94-106).

Lundqvist, D., Juth, P., & Öhman, A. (2014). Using facial emotional stimuli in visual search experiments: The arousal factor explains contradictory results. *Cognition and Emotion, 28*(6), 1012-1029.

Macmillan, N. A., & Creelman, C. D. (2004). *Detection theory: A user's guide*: Psychology press.

Markman, A. B., & Brendl, C. M. (2005). Constraining theories of embodied cognition. *Psychological Science, 16*(1), 6-10.

Marx, B. P., Forsyth, J. P., Gallup, G. G., & Fusé, T. (2008). Tonic immobility as an evolved predator defense: Implications for sexual assault survivors. *Clinical Psychology: Science and Practice, 15*(1), 74-90.

Mather, M., & Sutherland, M. R. (2011). Arousal-biased competition in perception and memory. *Perspectives on Psychological Science, 6*(2), 114-133.

McCall, C., & Blascovich, J. (2009). How, when, and why to use digital experimental virtual environments to study social behavior. *Social Influence, 4*, 138-154.

McCall, C., Blascovich, J., Young, A., & Persky, S. (2009). Proxemic behaviors as predictors of aggression towards Black (but not White) males in an immersive virtual environment. *Social Influence, 4*(2), 138-154.

McCall, C., & Singer, T. (2015). Facing off with unfair others: Introducing proxemic imaging as an implicit measure of approach and avoidance during social interaction. *PLoS ONE*.

McCall, C., Tipper, C. M., Blascovich, J., & Grafton, S. T. (2012). Attitudes trigger motor behavior through conditioned associations: neural and behavioral evidence. *Social cognitive and affective neuroscience, 7*(7), 841-849.

Misslin, R. (2003). The defense system of fear: behavior and neurocircuitry. *Neurophysiologie Clinique/Clinical Neurophysiology, 33*(2), 55-66.

Morie, J. F., Iyer, K., Luigi, D.-P., Williams, J., & Dozois, A. (2005). Development of a data management tool for investigating multivariate space and free will experiences in virtual reality. *Applied psychophysiology and biofeedback, 30*(3), 319-331.

Nicas, J. (2016, January 5, 2016). Augmented Reality Moves Forward With Investments, Products, *The Wall Street Journal*.

Niedenthal, P. M., Barsalou, L. W., Winkielman, P., Krauth-Gruber, S., & Ric, F. (2005). Embodiment in attitudes, social perception, and emotion. *Personality and social psychology review, 9*(3), 184-211.

Norris, C. J., Chen, E. E., Zhu, D. C., Small, S. L., & Cacioppo, J. T. (2004). The interaction of social and emotional processes in the brain. *Journal of Cognitive Neuroscience, 16*(10), 1818-1829.

Olsson, A., & Ochsner, K. N. (2008). The role of social cognition in emotion. *Trends in cognitive sciences, 12*(2), 65-71.

Palermo, R., & Rhodes, G. (2007). Are you always on my mind? A review of how face perception and attention interact. *Neuropsychologia, 45*(1), 75-92.

Parsons, T. D., & Rizzo, A. A. (2008). Affective outcomes of virtual reality exposure therapy for anxiety and specific phobias: A meta-analysis. *Journal of behavior therapy and experimental psychiatry, 39*(3), 250-261.

Peperkorn, H. M., Diemer, J., & Mühlberger, A. (2015). Temporal dynamics in the relation between presence and fear in virtual reality. *Computers in Human Behavior, 48*, 542-547.

Pessoa, L. (2008). On the relationship between emotion and cognition. *Nature Reviews Neuroscience, 9*(2), 148-158.

Quigley, K., Lindquist, K. A., & Barrett, L. F. (2014). Inducing and measuring emotion and affect: Tips, tricks, and secrets. *Handbook of Research Methods in Social and Personality Psychology. New York: Cambridge University Press*.

Rinck, M., Koene, M., Telli, S., Moerman-van den Brink, W., Verhoeven, B., & Becker, E. S. (2015). The time course of location-avoidance learning in fear of spiders. *Cognition and Emotion*(ahead-of-print), 1-14.

Rovenpor, D. R., Skogsberg, N. J., & Isaacowitz, D. M. (2013). The choices we make: An examination of situation selection in younger and older adults. *Psychology and aging, 28*(2), 365.

Russell, J. A. (2003). Core affect and the psychological construction of emotion. *Psychological review, 110*(1), 145.

Russell, J. A., Weiss, A., & Mendelsohn, G. A. (1989). Affect grid: a single-item scale of pleasure and arousal. *Journal of Personality and Social Psychology, 57*(3), 493.

Sagliano, L., Cappuccio, A., Trojano, L., & Conson, M. (2014). Approaching threats elicit a freeze-like response in humans. *Neuroscience letters, 561*, 35-40.

Schilbach, L. (2015). Eye to eye, face to face and brain to brain: novel approaches to study the behavioral dynamics and neural mechanisms of social interactions. *Current Opinion in Behavioral Sciences, 3*, 130-135.

Schilbach, L., Timmermans, B., Reddy, V., Costall, A., Bente, G., Schlicht, T., & Vogeley, K. (2013). Toward a second-person neuroscience. *Behavioral and Brain Sciences, 36*(04), 393-414.

Schmidt, N. B., Richey, J. A., Zvolensky, M. J., & Maner, J. K. (2008). Exploring human freeze responses to a threat stressor. *Journal of behavior therapy and experimental psychiatry, 39*(3), 292-304.

Singer, T., Kok, B. E., Bornemann, B., Bolz, M., & Bochow, C. A. (2015). The ReSource Project: Background, Design, Samples, and Measurements

Slater, M., Pertaub, D.-P., & Steed, A. (1999). Public speaking in virtual reality: Facing an audience of avatars. *Computer Graphics and Applications, IEEE, 19*(2), 6-9.

Vuilleumier, P. (2015). Affective and motivational control of vision. *Current opinion in neurology, 28*(1), 29-35.

Wingfield, N. (2015, December 13, 2015). In Virtual Reality Headsets, Investors Glimpse the Future, *The New York Times*. **Table 1**

|  |  |
| --- | --- |
| **Resilient emotion regulation factor** | |
| **Questionnaire** | **Factor loading** |
| ER89 Trait Resilience | .737 |
| CERQ Acceptance | -.139 |
| CERQ Catastrophizing | -.103 |
| CERQ Other Blame | .152 |
| CERQ Perspective | .337 |
| CERQ Planning Refocusing | .793 |
| CERQ Positive Reappraisal | .626 |
| CERQ Positive Refocus | .373 |
| CERQ Rumination | .104 |
| CERQ SelfBlame | -.073 |
| COPE Accept | .035 |
| COPE Active | .769 |
| COPE ActOut | -.029 |
| COPE Denial | -.117 |
| COPE Distraction | .010 |
| COPE Drugs | .006 |
| COPE Emotional Support | .044 |
| COPE Humor | .044 |
| COPE Instrumental Support | .053 |
| COPE Planning | .691 |
| COPE Positive Reinterpretation | .508 |
| COPE Religion | -.154 |
| COPE Self-blame | -.172 |
| COPE Withdrawal | -.315 |
| *Note:* These loadings derived from a principal components analysis as described in Singer et al., 2015. This factor accounts for 18.9% of the variance. | |

**Table 2**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Quadrant** | |  |  |  |  |  |
|  | **Valence** | **Arousal** | ***mean*** | ***CI*** | ***t*** | ***df*** | ***p*** |
| **Valence ratings** | **negative** | **low** | -0.50 | [-0.54, -0.47] | -30.8 | 314 | <.001 |
|  |  | **high** | -0.51 | [-0.54, -0.47] | -29.8 | 314 | <.001 |
|  | **positive** | **low** | 0.51 | [0.48, 0.55] | 33.0 | 314 | <.001 |
|  |  | **high** | 0.47 | [0.44, 0.50] | 28.3 | 314 | <.001 |
| **Arousal ratings** | **negative** | **low** | -0.27 | [-0.31, -0.23] | -12.7 | 314 | <.001 |
|  |  | **high** | 0.22 | [0.17, 0.27] | 8.9 | 314 | <.001 |
|  | **positive** | **low** | -0.31 | [-0.36, -0.27] | -14.2 | 314 | <.001 |
|  |  | **high** | 0.19 | [0.14, 0.24] | 7.7 | 314 | <.001 |

**Figures**



Figure 1: The four virtual worlds in The Wunderkammer.



Figure 2: The Affect Gallery. Participants freely explored The Affect Gallery (perspective and bird’s eye view, bottom right), an art museum with twelve slideshows varying in arousal and valence. Participants spent more time looking at, and came closer to, positively valenced slideshows. The effect of valence on gaze was particularly strong for high arousal images and amongst individuals high in resilient emotion regulation behavior. Significant factors are labeled in the chart titles: \* p<.05, \*\*p <.01, \*\*\*p<.001.

Figure 3: The Crowded Room. Participants encountered three different emotionally expressive agents in The Crowded Room, who wore neutral, angry, and sad expressions (bottom row). Participants gazed more at the emotional agents than the neutral agent (top row). They also avoided the angry agent as compared to the neutral and sad agents. Significant pairwise comparisons labeled: \* p<.05, \*\*p <.01, \*\*\*p<.001.

Figure 4: Room 101. In Room 101, participants encountered a series of startling events and disturbing episodes (third row). The more frightening participants found the world, the more they slowed down (top row) and the less they moved their head (second row), particularly during the more intense epochs (the bar charts present each epoch in chronological order). Resilient people were particularly likely to show this effect. Significant factors are labeled in the chart titles: \* p<.05, \*\*p <.01, \*\*\*p<.001.