Jean-Louis van Gelder

Virtual Reality for Criminologists: A Road Map

ABSTRACT

Virtual reality (VR) technology offers unique and as yet largely untapped potential for criminology. It can address problems that have traditionally plagued the field, provide an ecologically valid alternative for conventional research methods, and create novel possibilities for theory testing, and it allows for the study of phenomena that are difficult to research in the real world for ethical, safety, or practical reasons. This essay reviews the budding research literature using VR in criminogenic contexts, as well as relevant research from other disciplines, and explains the technology's basic features, current limitations, and ethical challenges. It concludes that within the foreseeable future, VR may become the criminological equivalent of the petri dish, offering the possibility to study the unfolding of highly complex behavioral processes in very detailed ways and help achieve step changes in our understanding of crime.

Criminology's key predicament resides in its object of study: crime takes place outside the researcher's field of view. The hidden nature of crime brings with it a series of practical, methodological, and ethical challenges that have been consequential for the development of the field in a variety of ways. For one thing, mainstream criminological research has tended to gravitate toward research questions pertaining to involvement in crime, rather than the actual conduct surrounding a crime event and the

Jean-Louis van Gelder is director of the Max Planck Institute for the Study of Crime, Security and Law in Freiburg, Germany, and full professor at the Institute for Education and Child Studies, Leiden University, the Netherlands. This work was financially supported by a European Research Council Consolidator Grant (no. 772911-CRIMETIME).

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decision-making that underlies it (Birkbeck and LaFree 1993). In terms of theory, apart from rational choice (Becker 1968; Clarke and Cornish 1985) and situational (e.g., Cohen and Felson 1979) theories, the field's main perspectives, for example, control theories (Hirschi 1969; Gottfredson and Hirschi 1990), developmental/life-course paradigms (Sampson and Laub 1993, 2003), labeling perspectives (Becker 1968), strain theories (Agnew 1992), and differential association and social learning frameworks (e.g., Sutherland 1947; Akers 1973), have all prioritized studying properties of individuals and the social factors that propel them into and out of crime (e.g., peers, romantic partners, gangs, parents, dispositions, neighborhoods) over their decision-making and explaining the crime event (Nagin 2007).

A review of staple research methods used in criminological research, such as interviews, surveys, self-report delinquency instruments, longitudinal panel studies, and official registration data, also bespeaks a field well equipped with tools that can measure criminal propensity and involvement decisions but limited in its ability to study and account for actual behavior. The resultant state of affairs is a field with an accumulated body of knowledge relating to background characteristics (i.e., characteristics of offenders and their environments) but for which the knowledge base of the immediate criminogenic foreground (i.e., the contextual and proximate factors that drive criminal behavior) is comparatively shallow. Given the many challenges the study of crime faces, the skewed nature of this knowledge base comes as no surprise.

Barring the possibility of observing crime in action, self-report surveys and interviews have been termed the data sources nearest to the actual behavior (Thornberry and Krohn 2000). Indeed, such methods have proved to be invaluable sources of information (e.g., Wright and Decker 1994, 1997; Shover 1996; Maruna 2001; Sampson and Laub 2003). Yet, their limitations are also well documented. Narrator inaccuracy manifested in the exaggeration or downplaying of actions; the burden of retrospection resulting in important events being forgotten, sequences reversed, or timing warped; and biases such as social desirability and demand characteristics distorting reality are only some of the challenges confronting these methods (Sykes and Matza 1957; Tulving 2002; Warr 2002; Krumpal 2013). As Baumeister, Vohs, and Funder (2007, p. 397) observe, research has abundantly shown that "people have not always done what they say

they have done, will not always do what they say they will do, and often do not even know the real causes of the things they do." Importantly, research is increasingly showing that much human behavior, including criminal behavior, is driven by automatic cognitive processes that by definition defy deliberate retrieval and, by implication, valid registration through interviews and survey instruments (Nisbett and Wilson 1977; Kahneman 2011; Nee et al. 2019).

Although challenges relating to introspective and retrospective methods are not restricted to the study of crime, they are compounded compared with domains in which people generally have little reason to conceal their intentions or conduct (Exum and Bouffard 2010). As Eck and Liu (2008, p. 196) observe, the study of crime is the only scientific enterprise where deception is intentional and endemic. Not only do offenders have an incentive to misrepresent the facts, the same may apply to victims and criminal justice actors in particular circumstances.

Observational methods can remedy these limitations to some extent but remain prone to observer subjectivity and pose other challenges. Few institutional review boards would approve research projects that propose to observe crime as it takes place, and, by the same token, few offenders welcome researchers to watch them on the job. The analysis of closed-circuit television (CCTV) footage could offer some recourse in this respect. A camera can record all the action occurring within its field of view, and video data can be infinitely replayed, paused, and slowed down. This provides a detailed frame-by-frame account of the events that unfold (Philpot et al. 2019). However, such footage may be prone to sampling bias, and similar to the analysis of registration data, linking observations to other relevant factors pertaining to individuals (e.g., psychological states, motivations, dispositions, background characteristics) is restricted and often impossible. Additionally, the correlational nature of observational research limits possibilities for drawing causal inferences.

In a similar vein, field experiments, a relatively rare occurrence in criminology (Weisburd 2003; Dezember et al. 2021), although more capable of establishing causality and mitigating potential confounders, are unable to provide access into the mechanisms that drive the behavior. Hence, an intervention may work for the hypothesized reason but also for other reasons not considered. Behavioral experiments into offending, such as those using undergraduate samples or online research platforms, have ethical and practical restrictions in terms of the type and severity of the

behavior that can be studied (e.g., Nagin and Pogarsky 2003), or they rely on behavioral intentions using vignettes rather than measuring actual behavior(e.g., van Gelder and De Vries 2012, 2014; Kamerdze et al. 2014). Furthermore, the decontextualized and generally contrived nature of experimental lab settings limits their ecological validity (e.g., Steinberg and Cauffman 1996; Blascovich et al. 2002). Importantly, these methods are not able to reflect the often chaotic circumstances and the "hot" affective states under which crimes are often committed (van Gelder, De Vries, et al. 2022). In short, the current arsenal of conventional research methods in criminology is inevitably subject to diminishing returns when it comes to understanding decisions to offend and testing the effectiveness of behavioral interventions.

I. Virtual Reality as Criminology's Critical Enabling Technology

The defining feature of virtual reality (VR) is its ability to perceptually transport users to a certain situation of interest. If properly designed, users immersed in VR become absorbed in the virtual environment (VE) and interact with it in naturalistic fashion, which provides novel opportunities for research, including addressing novel research questions and theory testing. That is, VR technology enables creating realistic situations that closely resemble their real-world analogues and allows for real-time observation of behavior while also providing access to cognitions, motivations, and emotions related to offending. Furthermore, VR allows for developing experimental settings that are easy to manipulate, consistent, replicable, and ecologically valid and rely on hardware and software that are increasingly coming within reach of the median research budget.

Whereas these possibilities of VR apply to the study of social behavior in general, this technology has particular potential for research on criminal behavior because crimes, in contrast to other types of behavior, generally do not lend themselves to direct observation or manipulation. Lab paradigms and online experiments are often unsuitable to study more severe types of crime because there is often an incentive for offenders to misrepresent the facts as they occurred or because research topics of interest to the criminologists' research agenda can be unethical or risky to study using conventional methods. By creating realistic immersive and interactive virtual replicas of criminogenic situations, researchers can

perceptually transport users to them and observe the criminal event as it unfolds in near real time, in an ethical way and without risk. However, by virtue of its ability to exceed the boundaries of the physical world, the potential of VR for criminology stretches beyond the possibility of studying crime in action and also has potential to enhance offender rehabilitation and desistance.

Although VR has not yet seen widespread application in criminology, there is a nascent research literature on a variety of phenomena relevant to criminologists, such as stereotyping and racial bias (Dotsch and Wigboldus 2008; Peck, Good, and Seitz 2021), disorderly conduct (Toet and van Schaik 2012), obedience and authoritarianism (Slater et al. 2006), aggression (Slater et al. 2013; van Gelder et al. 2019; van Gelder, De Vries, et al. 2022), moral dilemmas (Navarrete et al. 2012; Francis et al. 2017), self-regulation (Renaud et al. 2011; Kniffin et al. 2014), risk assessment (Fromberger, Jordan, and Müller 2018), sexual harassment (Neyret et al. 2020), delinquency (van Gelder, Hershfield, and Nordgren 2013; van Gelder, Cornet, et al. 2022), and crime (Nee et al. 2019; van Sintemaartensdijk et al. 2021). Furthermore, there is a growing evidence base showing that studies using VR can replicate well-established findings of social and behavioral science research (Bombari et al. 2015), including criminology (Nee et al. 2015; van Gelder et al. 2017; Meenaghan et al. 2018).

The remainder of this essay is structured as follows. After providing a nontechnical explanation of immersive VR and its key features, I explain why this technology is uniquely suited to study criminal conduct. Specifically, I elaborate on how VR can provide a more ecologically valid alternative to conventional research methods without sacrificing internal validity, create research possibilities that are hard to realize otherwise, and allow for the study of phenomena that may be difficult, or even impossible, to examine in the real world for ethical, safety, or practical reasons. I demonstrate how VR can advance research in several areas of criminology, such as decision-making, offender rehabilitation, theory testing, and assessing the effect of interventions, and I provide illustrations from existing research using VR technology. This is followed by a discussion of current limitations of the technology and considerations relating to ethical and practical issues, warnings regarding improper use, and cost. I conclude by providing a tentative sketch of where the technology could take criminology in the coming decade.

II. Virtual Reality: A Primer

VR refers to three-dimensional interactive and immersive environments that envelope the users and aim to generate the impression that they have stepped inside the virtual world. In plainer terms, VR can be described as human-computer interaction with an invisible interface that occurs in naturalistic fashion (Schultheis and Rizzo 2001). Interactivity is key in a VE, much more than with traditional media, because the user has a role within the medium, and his or her actions influence how the experience or scenario unfolds (Fox, Arena, and Bailenson 2009). Immersive VR is generally experienced through VR goggles, also referred to as head-mounted displays (HMDs), which provide stereoscopic view allowing for depth perception and three-dimensionality. HMDs are equipped with trackers that trace the location of the user and send it to the rendering computer (see fig. 1).[1] The computer, in turn, feeds the appropriate imagery back to the user through the HMD. The continuous flow of data between the computer and the user provides the latter with (near) real-time updating. This generates a naturalistic, or at least intuitive, viewing experience that matches the critical properties of our real-world viewing experience, which involves three-dimensional vision all around and visual scenes that are updated in sync with one's head movement (Pan and Hamilton 2018). In other words, the viewing experience in VR corresponds with what a user would see (and possibly hear and feel) if the scene were real (Rizzo and Koenig 2017). Essentially, any type of context or environment can be generated or simulated, and VR environments can be developed to model real-life situations (e.g., a courtroom, crime scene, street, or living room) but also situations that do not exist in reality or would be impossible in the real world (e.g., fantasy or science fiction worlds).

A. Immersion, Presence, and the Uncanny Valley

By shutting users off from all real-world visual input and replacing it with the computer-generated input, VR perceptually immerses them in the VE, which, if successful, is experienced as effectively real (Gonzalez-Franco and Lanier 2017). As vision is our dominant sense (i.e., more than 50 percent of neural tissue is related to vision; Sells and Fixott 1957), the visual aspect of VR is also its critical feature. However, other senses can

[1] Standalone or wireless devices have a processor and graphics processing unit built into the HMD and therefore do not need to be tethered to an external computer.

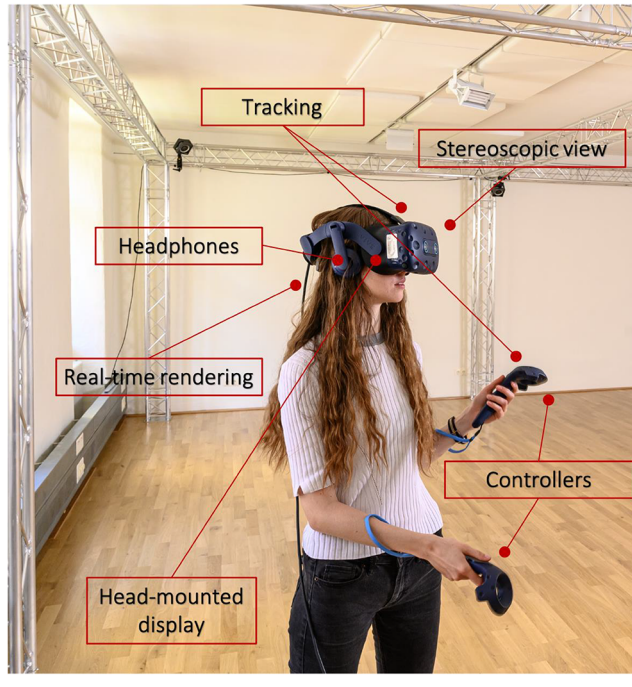

FIG. 1.—Virtual reality hardware and basic properties. Color version available as an online enhancement.

also be involved, and the visual experience can be complemented with software and hardware that render it more immersive, including spatialized sounds that users hear as if they are emanating from the surrounding three-dimensional auditory space (Loomis, Blascovich, and Beall 1999, p. 558). Furthermore, devices such as handheld controllers, gloves, and kinetic suits that provide haptic feedback, and incorporated scents, can add additional layers of immersion to the experience.[2] As such, VEs can include varying levels and combinations of multimodal sensory input, allowing audio, olfactory, and motion to be experienced simultaneously to the graphically rendered environment (Wilson and Soranzo 2015).

Whereas the term "immersion" denotes the objective amount and quality of sensory input provided to participants through hardware (Bombari

[2] Haptic feedback refers to using tactile sensations, such as vibration, pressure, touch, or force, as a means to communicate with users.

et al. 2015), the term "presence" refers to a user's subjective sense of "being there" (i.e., in the VE) and the tendency to respond to virtual events and environments as if they are real (Slater 2004; Slater et al. 2006). Different users can experience different levels of presence in the environment with the same level of immersion, depending on a range of factors such as state of mind, personality, and emotional state (Ling et al. 2013; Wilson and Soranzo 2015). The better the VR is able to present users with a three-dimensional experience, the more likely it is that they experience presence, which "occurs when part or all of a person's perception fails to accurately acknowledge the role of technology that makes it appear that s/he is in a physical location and environment different from her/his actual location and environment in the physical world" (Wirth et al. 2007, p. 495). Presence has also been described as the "illusion of non-mediation" (Lombard and Ditton 1997). Since the mind cannot be present in different places at the same time, feeling present in a VE implies psychological absence in the real world, which can trick the brain into accepting the VE as the "real" environment (Bailenson 2018*a*).

The higher the degree of presence achieved, the higher the anticipated correlation between a user's behavior in a real situation and a virtual equivalent (Bombari et al. 2015; Wilson and Soranzo 2015). To be sure, users remain aware that the environment they are seeing is not the real world, but, provided certain conditions are met, this does not prevent them from responding to it in realistic ways (Slater 2009, 2018).[3] As there is no real-world sensory input that can be used to base their actions on, users have little option but to rely on the input provided by the VR to guide their behavior. Research indicates that psychological transportation to the VR may occur on very brief timescales; it may only be a matter of moments before users react toward the virtual world as if it were real (e.g., Slater 2009; Slater and Sanchez-Vives 2016; Pan and Hamilton 2018).

[3] It is important to emphasize that the experience of presence is not about belief but about perception. The following explanation taken from Slater (2018, p. 432) is worth quoting in extenso as it makes the point well: "Presence is not about belief. Of course no one, not even when they are standing by a virtual precipice with their heart racing and feeling great anxiety, ever believes in the reality of what they are perceiving. The whole point of presence is that it is the illusion of being there, notwithstanding that you know for sure that you are not. It is a perceptual but not a cognitive illusion, where the perceptual system, for example, identifies a threat (the precipice) and the brain-body system automatically and rapidly reacts (this is the safe thing to do), while the cognitive system relatively slowly catches up and concludes 'But I know that this isn't real.' But by then it is too late, the reactions have already occurred."

To create an effective VE in which presence takes place, a user needs to let go of the awareness and knowledge that the stimuli in the VE are in fact not real, which is referred to as suspension of disbelief (Waterworth and Waterworth 2001). Aside from hardware limitations, the content of the VE can also break the suspension of disbelief (Waterworth and Waterworth 2001). Virtual landscapes, objects, and avatars should all be consistent with, and fit within, the visual and interactive design of the VE (van Gelder, Otte, and Luciano 2014). A clearly or even subtly wrong object in an otherwise realistic VE will look out of place and therefore be a possible source of disruption of the suspension of disbelief. Furthermore, attempts to create perfectly photo-realistic and lifelike virtual humans that fall below a certain threshold can come across as eerie and invoke uncomfortable feelings rather than invoking positive and empathetic responses, which negatively affects users' interaction with the environment. This phenomenon is known as the Uncanny Valley (Mori 1970; Stein and Ohler 2017). In such cases, deliberately less realistic and more stylized or cartoony figures may be preferred over more but not quite realistic ones.

It should also be noted that for establishing a strong sense of presence, the level of visual realism of a VR environment appears to be less important than other parameters (Sanchez-Vives and Slater 2005). Wilson and Soranzo (2015) note that realism might not be determined by visual fidelity but by psychological fidelity, that is, the extent to which the VE evokes the type of physiological or emotional response one would experience in real life. It has been suggested that "the fact that minimal cues are enough to induce presence implies that the absence of some degree of sensory information is not distracting, and is probably filled in by cortical processing" (Sanchez-Vives and Slater 2005, p. 337).

B. Avatars and Embodiment

Two types of virtual humans can populate VEs: those controlled by the user, commonly referred to as "avatars," and those controlled by algorithms, generally denoted as "agents." An avatar is the digital representation of a user whose behaviors are executed in real time by him or her (Nowak and Fox 2018). An agent, in contrast is a type of algorithm designed to accomplish a specific goal and whose behaviors are executed by a perceivable digital representation (Bailenson and Blascovich 2004).

As Gonzalez-Franco and Lanier (2017) note, ample research shows not only that people respond realistically to inanimate VEs and objects but also that they behave genuinely when interacting with virtual humans, which

are processed in the brain like real people. For example, norms, such as interpersonal distance, are kept when interacting with virtual humans (Gonzalez-Franco and Lanier 2017). People keep more distance from out-group compared to in-group virtual humans (Dotsch and Wigboldus 2008) and are also more likely to intervene in a virtual conflict when the "victim" is perceived as belonging to their in-group than when a member of an out-group (Slater et al. 2013). Furthermore, when having to speak in front of a virtual audience, people experience similar reactions as when in front of a real audience (e.g., increased heart rate, sweaty palms; Harris, Kemmerling, and North 2002), and shy males show higher anxiety when interacting with a virtual female than confident males (Pan et al. 2012). In a study by Slater and colleagues (2006) designed to replicate Milgram's famous obedience experiment (Milgram 1963), research participants delivered "electric shocks" to a virtual trainee when she made errors during a word association memory test. Even though participants were fully aware that neither the trainee nor the shocks were real, they tended to respond to the situation at the subjective (questionnaire responses), behavioral (withdrawal from the experiment), and physiological (increased heart rate, skin conductance) levels as if they were.

Finally, a relevant concept in behavioral research using VR, discussed in more detail below, is "embodiment," which refers to the replacement of the user's real body by her virtual substitute (i.e., the avatar body; Mol 2019). Under the right conditions, such as synchrony between the user's own physical body movements and those of her avatar, this substitution of a person's real body by an apparently coincident virtual body can lead to the illusion of embodiment (Bailey, Bailenson, and Casasanto 2016), also referred to as virtual body ownership. Even though a person's own body might look very different from the avatar's body she is controlling, the illusion of embodiment can lead to a strong feeling that the virtual body is the real one, and this can have profound cognitive and behavioral implications.

C. Measurement: Behavioral, Physiological, and Subjective Processes

It can be argued that to understand the full crime process, from inception through to commission and exit from location, a method is required that can capture both temporal as well as spatial dynamics (Keatley et al. 2021). VR can generate full and continuous geo- and temporally referenced data of this entire process and can simultaneously measure multiple variables at behavioral, physiological, and the subjective levels. Rather

than simply registering the manifested effect of an independent variable on a dependent variable, as, for example, is the standard in survey research, VR allows for identifying the chain of events that link an assumed predictor variable to the end state in very detailed ways. This can enable researchers, for example, to identify the different steps involved in the crime commission process (e.g., a crime script; Cornish 1994) and help identify complex interactional processes between the individual and the environment.

Most commonly, tracking in VR systems involves user head orientation through sensors integrated into HMDs, which allows for capturing in real time what a user is looking at with rates of 60+ frames per second. These trackers also register X and Y coordinates in the VE and hence provide spatial information, that is, how a user moves through a VE, such as a house or neighborhood, or the distance she keeps from others or certain objects in the environment. Depending on their level of complexity and immersion, VR systems also allow for simultaneously registering pose, force, and hand and other limb movement. Additionally, they can be combined with sensors measuring the user's physiological state (e.g., heart rate, skin conductance, cortisol level). This rich measurement can give excellent rewards and allows for measuring implicit and natural behaviors (Pan and Hamilton 2018). As these data are collected outside the conscious awareness of the user, they are much less prone to biases, social desirability, or deliberate manipulation. Think, for example, about the physiological reaction of would-be victims or bystanders to scenes of violence, the body pose of someone in reaction to an attempt at intimidation, or spatial movement of would-be offenders in response to increased police presence or security measures in an area.

Head orientation can speak to the underlying psychological phenomenon one intends to measure (e.g., attention, aggression, shyness; Yaremych and Persky 2019). Going further, it is possible to fit a VR system with eye tracking to increase the measurement precision of what users are seeing and for how long. Identifying what aspects of the environment people pay attention to, and which are disregarded, can provide even more insight into cognitive and affective processes, focus, and attentional states. People's eye movement may, for instance, reveal aspects of scenes that contribute to fear of crime that they would not consider reporting in surveys or would not normally be detected by conventional methods (Crosby and Hermens 2019). It also allows for establishing the extent to which certain features (e.g., security measures or other types of deterrents) have been noticed by users and what types of environmental cues offenders such

as burglars, carjackers, or sex offenders pay specific attention to. Fixation duration can be indicative of processing depth and hence the salience of certain features in the environment (Crosby and Hermens 2019). Short fixations indicate information scanning and lower-level automatic processing, while higher-level deliberate processing prolongs fixation durations (Glöckner and Herbold 2011). Furthermore, states of arousal (e.g., anger or sexual excitement) can be measured noninvasively via eye tracking by relying on pupil dilation (Rahal and Fiedler 2019). In short, eye tracking enables researchers to tap into the offender's, victim's, or bystander's perspective in an almost literal sense (e.g., Jacques, Lasky, and Fisher 2015).

These intricate measures of people's explicit and implicit behavior and their physiological reactions to pertinent stimuli in the environment can also be combined with more conventional research methods, such as surveys and interviews; decades of knowledge about offender and victim dispositions can be integrated with the proximal measurement of behavior in VEs. Integrated models of offender behavior that include both dispositions, or "traits," and time-varying variables, or "states," can be usefully tested in simulated environments and virtual scenarios (see van Gelder et al. [2019] and van Gelder, De Vries, et al. [2022] for examples). In a similar vein, VR offers the possibility to meaningfully study how person-environment interactions may result in crime. Through its ability to systematically vary elements of the environment (e.g., target hardening, police presence, availability of guardians) research can realize step changes in understanding this interaction.

D. Looking into the Black Box

Longitudinal panel models have traditionally been the method of choice to test criminological theory. Panels typically employ intervals of 1 year or more between waves and allow for identifying the temporal ordering between variables of interest. That is, researchers quantify a defined score or value on the independent variable(s) (e.g., level of self-control or number of delinquent peers during early adolescence) to predict scores on an outcome variable, such as self-reported violent offending in early adulthood. Beyond simply assessing whether self-control, delinquent peers, or their interaction at time 1 are predictive of individual behavior at time 2, the extended time frames of panel studies imply that such approaches offer limited insight into how the predictors shape the behavioral processes at stake and what happens in between waves. The scores on the outcome variable

reflect the end state, indicative of the manifested behavioral phenomenon, violent offending, but offer little in the way of identifying the processes leading up to it. A closely related concern regards the ability to draw causal inferences from longitudinal data. Valid causal inference is a given in randomized designs; in the nonrandomized setting the burden of proof is on the shoulders of the investigator to show that the relevant confounders have been taken into account, and it will be difficult to avoid lingering disagreement about the success of the attempt to achieve this (Raudenbush 2001, p. 523). Process, in short, remains criminology's black box.

VR can offer a glimpse into this black box. By way of illustration, consider peer influences. In his classic work *Companions in Crime*, Mark Warr (2002, p. 120) concludes that one reason why peer explanations of delinquency are contentious and unsettled is that the evidence for peer effects is largely correlational and often highly inferential: "despite strong and persistent evidence of peer influence in the etiology of delinquency, the exact mechanism(s) by which peers 'transmit' or encourage delinquent behavior among another remains a mystery." Warr's conclusion implies that the field is oblivious to the mechanisms through which one of the strongest correlates of delinquency affects the outcome variable. The use of immerse VEs could go some way into acquiring a better understanding into these mechanisms by staging criminogenic events that involve peers and subsequently observing their behavior during the process while controlling the pertinent stimuli in the situation. By creating faithful replications of real-life situations, the actual behavior can be observed as it unfolds, rather than having to rely on self-report indexes, and the entire behavioral process can be traced on different levels. That is, we can not only establish that a change occurred but also gain insight into how it occurred.

Iterating further on the association between delinquent peers and violence by way of example, a VR study could involve and immerse multiple participants (e.g., several peers) simultaneously in a VE. The specific situation of interest could be an event in which one or more virtual agents provoke the participant group in an aggressive way. Virtually any type of environmental variable considered relevant can be manipulated in such a scenario, such as aggressor characteristics (e.g., race, appearance, or number), location (e.g., mall, nightlife venue, or street corner), verbal and nonverbal communication by the aggressors (threats, pitch, tone, or posture), or time of day. Outcome variables that easily come to mind are the verbal and nonverbal responses by participants, (changes in) distance between the participants and aggressors, gaze and eye movement, and intended or

actual use of force (measured through haptic feedback). Trait and state measurements of self-control or other variables (e.g., gender, attitudes, personality traits) can be added to the research design with relative ease.

By way of comparison, consider attempting to assess such behavior with a behavioral field or lab experiment. Here the typical approach is to code elements of a social interaction of interest in real time or via video recordings. Processing and coding of such interactions for verbal and especially nonverbal content are time consuming and resource intensive. Furthermore, such an experiment would require trained actors able to credibly and reliably stage the event, be highly resource intensive, and be comparatively restricted in terms of its ability to experimentally vary parameters of interest for both ethical and practical reasons. In a virtual interaction, however, the behaviors can be collected by the VR system that runs the experiment. For example, to accurately update the user's visual perspective, the system registers head movement at 60+ instances per second. Such data can be to create continuous tracings of physical behavior throughout the virtual interaction. These data can be processed, visualized, and analyzed in a variety of ways, which can lend crucial insights into psychological and social processes.

III. What Is in It for Criminology?

The potential benefits for application of VR in the behavioral and social sciences more broadly, such as its ability to achieve high levels of ecological validity while maintaining researcher control and hence without compromising internal validity, standardization of research designs and stimulus material, and replicability, have been described at length elsewhere.[4] In this section, I therefore particularly elaborate on why VR is uniquely positioned to advance our understanding of criminal behavior. Specifically, I highlight the possibility of studying crime in action; the ability to create contexts that are difficult, costly, or impossible to achieve in the real world; and the potential of VR to establish safe and ethical research settings. I illustrate these points with examples of existing research.

[4] For excellent reviews, see Fox, Arena, and Bailenson (2009) for communication science, Mol (2019) for behavioral economics, Bombari et al. (2015) and Pan and Hamilton (2018) for experimental psychology, Yaremych and Persky (2019) for social psychology, Bohil, Alicea, and Biocca (2011) for neuroscience, and Rizzo and Koenig (2017) for clinical psychology.

A. Studying Crime in Action

One problem that has plagued criminology since its genesis is that due to its illegal, and hence largely hidden, nature, the actual commission of crime can rarely be observed. Opportunities that allow for the systematic empirical study of offending or that lend themselves to experimental manipulation are rarer still (van Gelder and Van Daele 2014). As important, even if it were practically feasible to study crime as it takes place in a given instance, ethical considerations militate against the feasibility of such research. To accommodate for the fact that the behaviors of interest cannot be directly observed, criminologists have resorted to retrospective and indirect methods, such as interviews and surveys, to study offending processes. As was outlined earlier in this essay, although these methods have proved invaluable for our understanding of crime, their introspective and retrospective nature pose limitations on their ability to explain actual behavior, while also being vulnerable to deliberate manipulation.

One of the advantages of VR is that, rather than having to rely on reports by offenders or other relevant parties, such as victims or bystanders, recounting how past events took place, it allows for studying actual behavior in real time and in multifaceted and detailed ways (see also Sec. II). Instead of recording and analyzing verbal statements and self-disclosure, VR systems can measure behavior (e.g., spatial movement, body posture, gaze) in minute detail and trace it on a continuous basis. VR also allows for the simultaneous measurement of physiological states (e.g., heart rate, skin response). Against this level of detail, surveys, panel data, and interviews stand out as relatively crude instruments for obtaining insight into behavior and the factors driving it. That is, asking offenders to retrospectively report on how they commit crime, potentially months or years after the crime has occurred, will lead to loss of detail and almost certainly erodes the accuracy of the descriptions that offenders and others provide of what transpired during the crime event.

Importantly, even when inquiring about concurrent events, interview and survey techniques provide only limited access to both higher and lower order cognitive processes. As was forcefully argued decades ago by Nisbett and Wilson (1977, p. 232), "when people attempt to report on their cognitive processes, that is, on the processes mediating the effects of a stimulus on a response, they do not do so on the basis of any true introspection. Instead, their reports are based on a priori, implicit causal theories, or judgments about the extent to which a particular stimulus is a plausible cause of a given response." Hence interviews and surveys are

unlikely to accurately tap into the processes that may play critical roles in offender decision-making, such as emotions and visceral drive states (van Gelder 2013). Indeed, ample evidence suggests that feelings such as fear and anger exert a strong influence on decision-making processes and that people are generally oblivious to their effect on behavior (Loewenstein 1996; Wilson and Gilbert 2003). Furthermore, cognitive and behavioral scientists have convincingly shown that automatic and unconscious processes (e.g., appraisal of one's environment) exert a pervasive and ubiquitous influence on human perception, information processing, judgments, and behavior (e.g., Wilson 2004; Custers and Aarts 2010; Kahneman 2011). Even behaviors that were once deliberate (e.g., learning how to drive a car) can become automatic after repeated practice (DePaulo 1992). The fact that these processes occur outside of conscious awareness renders instruments that rely on effortful retrieval unsuitable to uncover them by default.

As was also mentioned earlier in this essay, the use of VR carries another advantage over conventional methods, particularly when it comes to understanding behavior in the criminal justice context. The socially undesirable and unethical nature of criminal conduct increases incentives for untruthful reporting. The possibility to observe and measure actual behavior, rather than verbal accounts of behavior, lessens this concern. People are, for example, more practiced in controlling what they say than in controlling their (nonverbal) behavior (Caso et al. 2006). Critically, the fact that words are generally more important than nonverbal behavior in the exchange of information makes people more aware of what they are saying than of how they are behaving (Caso et al. 2006). Additionally, an important precondition for controlling one's behavior is actually being aware of it. The immersive nature of VR may lead people to more easily "forget" about their behavior, especially when being involved in an absorbing task (see the next subsection for an example), and to be less self-conscious when interacting with others compared to interacting in, say, a laboratory setting (Jouriles et al. 2009).

VR scenarios can be modeled after relevant contexts for crime researchers, such as classrooms, courtrooms, prison cells, streets, or neighborhoods. Within such simulated environments, it is possible to stage activities that mimic their real-life analogues (e.g., a burglary or an assault) and implement them as part of assessment, measurement, or intervention strategies. By virtue of the possibility to develop criminogenic VEs that resemble their real-world counterparts and the possibility of real time

measurement of behavior under controlled circumstances, VR allows for the observation of crime in action (i.e., criminal behavior as it takes place; van Gelder et al. 2017). Furthermore, virtual scenarios conform to the demands placed by controlled lab experiments, yet they do not suffer the problem of lack of ecological validity or contextual realism. That is, whereas the realism of the VE mimicking a situation of interest contributes to the ecological validity of the research design, researcher control over the (entire) environment and cue exposure establishes internal validity.

Evidently, the application of VR has merit only when offenders behave in similar ways in VR as they do or would do in real life. Hence, established findings from criminological research should replicate in research using VR. There is emerging evidence that this can be the case.

B. The Virtual Burglary Project

1. *Overview.* One example of research aiming to study crime in action is the Virtual Burglary Project (VBP), which is a collaboration led by researchers from the Max Planck Institute for the Study of Crime, Security and Law and the University of Portsmouth. In VBP research, incarcerated burglars, and sometimes other groups, are invited to scope virtual neighborhoods for opportunities, select a target to burglarize, or commit a burglary (e.g., Nee et al. 2015, 2019; van Gelder et al. 2017; van Sintemaartensdijk et al. 2021, 2022). They are instructed to go about it as they would in the real world. During this "virtual burglary" process, the VR system tracks participant behavior in real time, such as gaze, spatial movement, target selection, entry and exits points to houses and the neighborhood, and which items are stolen and in what order. By mimicking the, comparatively contained, burglary event while maintaining experimental control, this approach allows for studying a burglary event as it actually unfolds from inception to exit.

The studies that have been conducted within this research program have yielded a number of insights. Perhaps first and foremost, they have shown that burglary behavior in the VE resembles to a large extent the behavior of burglars in the real world. Indeed, VBP research has replicated findings of earlier burglary research using conventional research methods (Nee et al. 2015, 2019). For example, this work has shown that offenders target end of terrace houses more often than houses in the middle of a row, that burglars enter the back of houses much more often than the front, and that search patterns in a real house and a virtual replica of that same

house are largely identical (see fig. 2). Furthermore, this research has identified clear differences in the decision-making of burglars compared with other groups in ways commensurate with expertise in other behavioral domains (Nee et al. 2019).[5] Van Gelder et al. (2017), in a study using a student sample, showed that physiological responses of participants to the burglary event (i.e., elevated heart rate) resembled those that could be expected in the real world. Specifically, the heart rate of participants peaked at the moment they entered the house to burglarize it and dropped quickly toward baseline levels immediately upon exiting the house.

An experimental study speaking to the potential of VR for theory testing, examined the effect of different levels of guardianship on burglar deterrence (van Sintemaartensdijk et al. 2021, fig. 1). Incarcerated burglars were asked to appraise a virtual neighborhood in search of a burglary target. During the appraisal process, depending on the experimental condition, they were exposed to different levels of guardianship, ranging from a merely present guardian to an intervening guardian. The presence of a (single) virtual guardian in the neighborhood had a deterrent effect, increasing the perceived likelihood of apprehension and perceived community cohesion, while decreasing neighborhood attractiveness for burglary, compared to the control condition in which no guardian was present. Deterrent effects of incremental levels of guardianship were negligible however. That is, a deterrent effect emerged irrespective of the actions of the guardian toward the participating burglars (e.g., looking at them or verbally addressing them). Furthermore, this study, in line with previous VBP studies, showed that burglars appraised the neighborhood differently from a control group of nonburglars. Importantly, van Sintemaartensdijk and colleagues (2021) showed that burglars in the sample responded to the virtual guardian in ways that are qualitatively identical to what we know about offender responses to actual human guardians, suggesting that offenders too respond to virtual humans in realistic ways.

A related study by the same researchers and among the same research sample examined the deterrent effects of neighborhood watch signs and signs suggesting increased police presence in the neighborhood (van Sintemaartensdijk et al. 2022). Although findings again differed for both groups, the deterrent effects of both types of signs were found to be negligible, suggesting interventions based on such measures are unlikely to be effective.

[5] Note that the VE by Nee et al. (2015, 2019) was presented on a laptop computer, rather than being delivered via an HMD.

FIG. 2.—Screen shots of virtual neighborhood (van Sintemaartensdijk et al. 2021). Color version available as an online enhancement.

VR can be integrated usefully in mixed-methods designs also. Meenaghan et al. (2018) demonstrated the merit of using VEs among burglars in a mixed-method design by combining VR with interview techniques and think-aloud protocols, with the aim of enhancing offender recall. Incarcerated burglars committed a burglary in a simulated VE on a laptop computer and "thought aloud" while undertaking it. Think-aloud protocols intend to make thought processes, rather than just their end product, as explicit as possible during the performance of a task (Ericsson and Simon 1984). The results of Meenaghan and colleagues (2018) support the assumption that much behavior of burglars during different stages of the burglary event is driven by automatic and habitual decision-making. Results

from the interviews with participants following the virtual burglary indicate that the simulated environment effectively reinstated the criminogenic event, increased participant engagement, and enhanced recall.

The type of triangulation of research methods by Meenaghan and colleagues (2018) bypasses the challenges that plague conventional introspective and retrospective methods in different ways. First, think-aloud protocols assist in verbalizing automated processes, which helps uncover the cognitive and decision processes that have become automatic through repeated practice. Second, by reducing the time gap between the commission of the (virtual) crime and the interview to a few minutes rather than weeks, months, or years, recall problems are avoided, as is the tendency to provide answers based on confabulation. Third, the use of VR allows for discussing the actual behavior with participants rather than solely relying on subjective accounts of that behavior by the actor. Finally, the engagement of participants with a VR task can be an effective way to build rapport and encourage participants to talk more openly about their experiences, skills, and knowledge, to the point of providing helpful suggestions on how to improve the VEs for future studies (see Nee et al. 2019).

2. Virtual Reality as a Mobile Research Lab Inside Prisons. Research in the VBP program highlights another advantage of VR for crime research, namely, the ability to conduct VR research inside prisons and to collect data among incarcerated offender samples. This goes beyond what is commonly understood as "prison-based research." In effect, it involves the import of VR hardware systems inside prison walls to psychologically transport participants to the relevant virtual criminogenic situation outside of the prison environment. In essence, this implies that the technology allows for bringing a crime scene to offenders to study their behavior in context (see Sec. III.D.3 for a discussion of other potential applications of VR inside prisons).

The benefits are various. The ability of VR to systematically vary key situational parameters to examine their effect on behavior allows for the execution of controlled experiments that can provide not only fundamental insight into the behavioral processes underlying crime but also input for crime prevention. Second, it facilitates data collection because of the accessibility of offenders in prison settings in substantial numbers. In our experience, incarcerated offenders are often willing to lend their services to researchers, perhaps even more so if the opportunity involves the possibility of experiencing VR. A third benefit relates to the fact that incarcerated offenders may respond differently compared to active offenders. As

Topalli, Dickinson, and Jacques (2020) observe, a drawback of interviewing offenders in prison is that their memories and assessments of their offending before they were caught are colored by their current institutionalized context. The ability of VR to psychologically transport users outside of the prison setting and immerse them in a criminogenic situation of interest, rather than asking them to recount how past events occurred, may reduce concerns to this end. That said, the extent to which the institutional context continues to affect responses and behavior is ultimately an empirical question to be settled by future research.

C. Providing Context

1. *Overview*. The VBP is an example of VR-based research in which the aim is to mimic the real world as closely as possible. Another, and related, way in which VR can meaningfully contribute to criminology relates to its ability to provide relevant context and to create plausible research settings that are difficult, or even impossible, to realize in the real world. Because all psychological mechanisms require environmental input for their activation (Buss 2012), it follows that human behavior is relative to the context in which it takes place (van Gelder and Nagin 2023). To test decision models, it is therefore important that research designs provide contextual cues to activate the relevant associations and emotions (Loewenstein 1999; Innocenti 2017). Here, context refers to aspects of not only the physical environment (e.g., lighting, disorder) but also the social environment (e.g., peers, guardians, instigators, co-offenders; Barnum and Pogarsky 2022).

Providing situational context in the study of behavior has proved challenging, not just for criminologists but for behavioral researchers more generally. For one thing, the research process can be hampered by the multitude of variables playing a role in human interaction over which the researcher has little control. Research is typically subject to a trade-off between experimental control and ecological validity (Blascovich et al. 2002). This has generally resulted in highly controlled but also contrived situations at the cost of losing ecological validity (Blascovich et al. 2002). The most controlled experiments—often conducted in sterile laboratory environments with stripped-down variables—result in a significantly less lifelike context, thus limiting realism and ecological validity. Behavioral field experiments and ethnographic work among active offenders (e.g., Shover 1996; Jacobs and Wright 1999; Topalli and Wright 2013), however, although high in ecological validity, tend to be subject to myriad

extraneous variables, observer subjectivity, and the challenge of quantitatively coding observed phenomena.

One approach that has been used to provide some contextual information while retaining control over the variables contained in the situation is the use of vignettes or written hypothetical scenarios (e.g., Exum 2002; Schoepfer and Piquero 2006; Armstrong and Boutwell 2012; van Gelder and De Vries 2012, 2014). Early pioneering work by Nagin and colleagues (Klepper and Nagin 1989; Nagin and Paternoster 1993, 1994) started using vignettes to provide context surrounding (hypothetical) offenses thought to be relevant for people's decisions (van Gelder and Nagin 2023). This work sparked a new research tradition within criminology and played a foundational role in shaping what has come to be known as the rational choice paradigm in criminology.

Yet, short narratives form at best only a faint reflection of the circumstances that are typical of situations in which crime and conflict take place and have difficulty communicating the emotional content that tends to characterize such situations (e.g., van Gelder 2013) and to activate the relevant associations. Furthermore, written scenarios remain heavily reliant on the imagination of research subjects, who are required to mentally project themselves into the described situation of interest, and insensitive to individual differences in people's ability to do so, as well as their attentional and motivational capabilities (Loomis, Blascovich, and Beall 1999; van Gelder, De Vries, et al. 2022).

VR can remedy such limitations to an important extent, as it allows for retaining experimental control over all relevant stimuli in the environment while also being able to generate realistic situations that are high in ecological validity. That is, rather than describing the situation of interest and relying on participants' ability to imagine it, VR can faithfully render it and provide substantial contextual detail. The immersive and perceptually enveloping character of VR may further add to the experience of transportation by effectively shutting off sensory input from the physical world and hence cancel out potential sources of distraction. A computer or television screen, in contrast, can easily be looked away from, hence diverting attention and reducing the experience of presence (van Gelder et al. 2019; van Gelder, De Vries, et al. 2022). By more directly eliciting participants' cognitive and affective processes, VR technology can also substantially augment mundane realism and reduce variability in the results of manipulations (Loomis, Blascovich, and Beall 1999, p. 559). Precisely because VR is so experiential, it allows for triggering the mental, emotional, and visceral

emotions (e.g., thrill, fear, arousal) that are typical of situations that involve offending.

An additional advantage of VR over written vignettes regards its ability to measure physiological responses to specific aspects of the situation in real time (see also Sec. II.C). Physiological measurements can be synced to the VR, thus allowing for measuring participant reactions to specific occurrences within a scenario.

2. *The Virtual Scenario Method.* To address the limitations regarding context and the inability to induce relevant emotions, van Gelder and colleagues developed a VR scenario approach using immersive 360° video technology (van Gelder et al. 2019; van Gelder, De Vries, et al. 2022). Using this technology, a faithful reproduction of reality is generated by using multiple cameras that together record the full 360° × 180° field of view (see fig. 3). The goal is to perceptually immerse research participants in the situation of interest and to let them experience the scenario through VR goggles rather than having them read it off a sheet of paper or computer screen.

In a first study, van Gelder et al. (2019) visualized a commonly used "bar fight" scenario (e.g., Exum 2002; Mazerolle, Piquero, and Capowich 2003; Armstrong and Boutwell 2012), which describes a conflict between two patrons in a bar. The scenario was played out by actors in a barroom setting, an actual Irish pub, and filmed from the first-person perspective using a 360° camera rig (see van Gelder et al. 2019 for details). This enabled participants to experience the scenario through the eyes of the protagonist. In this study, the VR version of the scenario was experimentally tested against a written version of the same scenario among attendees of a large music festival. Festival goers ($N = 153$) who volunteered to participate in the study were randomly assigned to one of the conditions (written scenario vs. VR scenario) and responded to a series of questions relating to their intention to react aggressively, perceived risk, anticipated shame or guilt, presence, perceived realism, and anger, after either experiencing or reading the scenario. The results indicate that both presence and perceived realism were higher for the VR scenario compared to the written scenario and that presence and anger mediated the relation between the condition and intention to aggress. No differences in aggressive intentions emerged between conditions in this study.

These findings were replicated and extended in a follow-up study among university students using the same scenario design (van Gelder, De Vries, et al. 2022). The follow-up study also added three robust personality

FIG. 3.—360° camera rig (*A*) and 360° screen shot (*B*) of bar fight scenario in van Gelder et al. (2019) and van Gelder, De Vries, et al. (2022). Color version available as an online enhancement.

correlates of aggressive behavior to the design, namely, agreeableness, emotionality, and honesty/humility, in order to test a trait-state model specifying the pathways through which personality is related to intentions to behave aggressively. The findings of van Gelder et al. (2019) were largely replicated in this study. Furthermore, in line with expectations, agreeableness mainly operated on aggressive intentions via anger, emotionality via the state of fear, and honesty/humility through anticipated shame or guilt. This study also found a difference in anger between conditions; people who experienced the scenario in VR reported more anger than those in the control group, supporting the claim that VR is better able to elicit emotions than written vignettes.

In conjunction, these initial studies hint at some of the promise virtual scenarios have for crime research. Not only do they provide a more ecologically valid alternative to written scenarios while maintaining researcher control, they also illustrate how VR can be combined with survey data to examine how dispositions influence the ways people react to (specific aspects of) a situation and identify the mechanisms through which they lead to criminal conduct. Furthermore, van Gelder et al.'s (2019) study, which was conducted at a music festival, illustrates the mobile nature of VR and how temporary "pop-up" research labs can be set up on site relatively easily, akin to lab-in-the-field experiments.[6]

One noteworthy limitation of the virtual scenario studies discussed above, however, is that rather than measuring actual behavior, they relied on behavioral intentions; that is, participants report what they would do in the situation. Furthermore, the scenarios were linear in nature. Lacking the possibility for interaction, participants had no possibility to influence the course of events in the scenario. Although this facilitated comparison to written vignettes, it is at odds with real-life situations.

In terms of criminological theory, van Gelder, De Vries, et al.'s (2022) findings have implications. Contextually impoverished or detached descriptions of events in prior criminal decision-making research may have, inadvertently, reinforced the idea that crimes are the result of rational decisions in which feelings play no significant or systematic role, as argued by influential criminal decision-making perspectives (e.g., Clarke and Cornish 1985; Clarke 2013; van Gelder et al. 2014). The van Gelder, De Vries, et al. (2022) finding that anger was significantly higher in the VR condition compared to the written scenario suggests that vignette studies intending to establish the effect of emotions on criminal decision-making may have systematically underestimated their importance and that rational choice based perspectives provide inaccurate, or at least incomplete, descriptions of choice processes (see also Loewenstein, Nagin, and Paternoster 1997).

To get a better sense of how emotions and visceral states affect behavior, a follow-up virtual scenario project experimentally induces them in a VR scenario and compares them to an emotionally neutral control condition

[6] Lab-in-the-field experiments combine elements from both lab and field experiments by applying standardized, validated lab paradigms among relevant populations in naturalistic settings (Gneezy and Imas 2017). Targeting the relevant population and setting increases the applicability of results and ecological validity, whereas the standardized paradigm permits the experimenter to retain control, while still allowing for direct comparisons across contexts and populations (Gneezy and Imas 2017, p. 440).

(Barnum et al. 2023). In the experiment, male participants are either provoked and taunted by another patron in the scenario or seduced by a female before witnessing a violent event in a bar or an event involving sexual harassment. By comparing versions of the scenario in which feelings have been experimentally induced to versions where they have not, the effect of subjectively reported feelings as well as physiological reactions on behavioral intentions can be identified. Importantly, this approach allows for identifying not only the strength of the association between feelings and intentions to behave aggressively but also the extent to which emotions influence cost-benefit considerations and measure their direct and indirect effects on the former.

D. Providing Safe and Ethical Research Settings

The virtual scenario research discussed in the previous section not only suggests superior validity of the VR version of the scenario compared to the written version but also highlights another pertinent feature plaguing conventional research methods that attempt to study violence and similar behaviors: staging a real credible violent event is not only complicated, and difficult to reliably reproduce from trial to trial, but also involves many ethical and risk-related obstacles (Levine 2014). VR can sidestep common problems relating to risk or ethics in the study of this type of behavior; neither avatars nor research participants can get hurt.

Flight simulators that provide training environments for pilots are an example of how VEs have been usefully applied in domains where using real-life situations carry risk (Fox, Arena, and Bailenson 2009). Flight simulators, often considered to be precursors of modern-day VR, were initially developed because of the need for safe training environments without the risk of injury for pilots or damage to aircraft in case of mistakes (Caro 1988). Similar to flight simulators, VR places the user in an artificial environment believed to be a valid substitute for the actual experience. By virtue of its ability to mimic the real world in credible ways, VR can turn circumstances that would normally involve risk into safe situations in which people can practice and act in a controlled setting and make errors without real consequences. Apart from flight simulators, think of training in complex surgical procedures or firearms training for police officers. As risks and ethical challenges are woven into the fabric of the study of crime, VR offers recourse in this context as well. Below, I discuss research from three different domains in which VR-based research overcomes such challenges plaguing conventional approaches.

1. *The Bystander Effect.* The bystander effect refers to the well-known assumption that people's feelings of responsibility to intervene in emergencies diffuse with the presence of other bystanders (e.g., Darley and Latané 1968; Fischer et al. 2011). Ideally, human behavior during critical situations should be observed in real time, but this would be challenging, especially when the behavioral response to a violent event is the central research focus. Recent work based on the analysis of CCTV footage of actual events in three different countries (South Africa, the United Kingdom, and the Netherlands) shows that this novel methodological approach sheds new light on the intervening behavior of bystanders (e.g., Philpot et al. 2019, 2020). Philpot and colleagues (2020) found that in 9 out of 10 public conflicts at least one bystander acts to help. This finding changes the common narrative from an absence of helping behavior toward a new understanding of what makes intervention successful or unsuccessful (Philpot et al. 2020). Processing and coding of social interactions, while promising, is, however, cumbersome and resource intensive.

Additionally, little information apart from the observable features of those involved in the interactions can be collected, and researchers are dependent on the material that is available to them. As Rovira and colleagues (2009) note, the correlational nature of field studies of the bystander effect make it difficult to extract causal relationships because of the inability to control for confounding variables. In a virtual interaction, however, physical behavior can be registered by the VR system that runs the experiment, and researchers can additionally get access to the thoughts, feelings, and not directly observable characteristics, such as dispositions, preferences, and attitudes, of their research participants via physiological and survey measures.

Slater et al. (2013) used immersive VR to investigate whether supporters of Arsenal Football Club would intervene during a physical attack between two virtual humans in a bar. The central question in their study was the extent to which the participant, the bystander in the scenario, would try to intervene and whether the relationship of the bystander with the victim would affect the helping behavior of the participant. The results indicated that participants in the in-group condition, in which the victim was also an Arsenal fan, made more attempts at physical and verbal intervention compared to participants in the out-group condition, in which the victim was not an Arsenal fan.

Jouriles et al. (2016) studied bystander behavior in response to violent sexual advances. The researchers designed a VR procedure that involved virtual scenarios of various situations that could conceivably escalate to a

female being sexually victimized. The observed bystander behavior during the virtual scenarios correlated with self-reported responsibility and intention to intervene as assessed before entering the VR scenarios. These findings provide initial support for the validity of a VR-based approach to investigate the bystander effect.

2. *Moral Dilemmas.* Moral decision-making is another relevant domain with potential for criminology. One frequently used paradigm to study moral decision-making is the well-known Trolley Problem (Thomson 1976). Here individuals must decide whether to flick a switch to redirect a runaway trolley car threatening the lives of five people. Flicking the switch would unavoidably result in the death of another, sixth, person but save the five lives. The general finding, based on self-report survey instruments, is that most people prefer the utilitarian option to sacrifice one life to save five. Navarrete and colleagues (2012), examining the Trolley Problem in an immersive VE rather than asking participants to state their preference, asked them to press a lever to redirect the boxcar (which they used instead of a trolley). Around 90 percent of the study participants opted for the utilitarian option in the VR paradigm, which is comparable with findings of the previous survey research. Importantly, the authors found that emotional arousal, measured through skin conductance, was associated with a reduced likelihood of acting to achieve a utilitarian outcome and that emotional arousal was greater when behaviorally resolving the dilemma required commission of an action rather than omission of an action (see also Francis et al. 2017). They conclude that "these findings are important, as they affirm the empirical link between emotion and moral action and provide preliminary evidence that similar neurophysiological processes may mediate moral judgment and action. Furthermore, these findings can be seen as setting the empirical groundwork for investigating the contexts in which judgment and action may dissociate" (Navarrete et al. 2012, p. 368).

3. *Offender Rehabilitation.* Apart from transporting offenders to theoretically relevant virtual criminogenic contexts to examine their decision-making, VR can also be used to transport incarcerated individuals to the world outside closed institutions for other purposes such as rehabilitation, for example, to practice dealing with challenging situations that they are likely to encounter after their release (e.g., self-checkout in supermarkets, housekeeping activities), to practice skills that are necessary to return successfully to society and maintain a noncriminal lifestyle (e.g., social interaction with strangers, applying for jobs), or for therapeutic purposes

(e.g., posttraumatic stress disorder therapy, substance abuse treatment, aggression regulation training). Taking aggression regulation training for offenders as an example, possibilities for exposure to actual provocation in forensic settings is limited. This makes it difficult to train violent offenders to control their anger by provoking them using real-life social situations (Klein Tuente et al. 2018). The use of VR can render it safer to do this, as the trainee faces a virtual character who cannot get hurt, rather than an actor or a trainer. In addition, it may feel safer for the trainees to express their aggression toward an avatar than toward a human being, as there is less concern regarding jeopardizing the therapeutic relationship (Klein Tuente et al. 2018).

Preparing incarcerated offenders for the job market is another example of how VR can be used in a meaningful way. Smith and colleagues (2023) conducted a (nonimmersive) randomized experiment into the feasibility and initial effectiveness of virtual job interview training, comparing "service as usual" to virtual job interview training combined with service as usual. Service as usual consisted of a "15-hr preemployment preparation workshop designed to enhance employability skills related to the job search, completing job applications, cover letters, resume writing, and job interviewing" (Smith et al. 2023, p. 278). The researchers found that adding a virtual component improved interview skills and motivation, reduced anxiety, and led to greater employment measured at a 6-month follow-up.

Although training in prisons can be achieved through other means, these environments tend to be restricted in terms of the opportunities they can offer. VR offers a high degree of visual fidelity (i.e., virtual training environments can be developed to closely resemble the type of environments where actual behavior occurs, e.g., a bar, street corner, or office) and allows for practicing with a potentially infinite number of (standardized) situations or scenarios, with avatars that do not grow tired and cannot get hurt. Due to the scalability of VR, there is also potential for widespread application. Furthermore, VR may be experienced as more engaging and motivating than traditional intervention programs, especially among young offenders who tend to be digital natives (Cornet and van Gelder 2020, 2023). Furthermore, it may be particularly suitable for this group as its immersive character leaves less room for distraction (e.g., from others present) and poses fewer demands on the imaginative abilities of participants—which are often required for role-playing exercises, thereby contributing to stronger feelings of presence and engagement (Cornet and van Gelder 2020).

IV. Transformation

Thus far, I have primarily focused on the ability of VR to mimic the real world. However, as Slater and Sanchez-Vives (2016, pp. 1–2) observe: "the real power of VR is not necessarily to produce a faithful reproduction of 'reality' but rather that it offers the possibility to step outside of the normal bounds of reality and realize goals in a totally new and unexpected way." One illustration of this possibility is provided by research using virtual embodiment.

As was already mentioned earlier, VR can be employed to have users embody avatars with characteristics that differ from their own in a perceptually realistic manner (Slater and Sanchez-Vives 2016; Gonzalez-Franco and Lanier 2017). Manipulating a user's sense of self through altered avatar design can produce nonconscious perceptual or behavioral effects, in spite of users remaining aware that they are in an artificial environment (Bailenson and Segovia 2010; Gonzalez-Franco and Lanier 2017). Provided certain conditions are met, virtual embodiment can lead to the temporary illusion of body ownership or "transformation" (Slater et al. 2010; Bombari et al. 2015; Mol 2019). The Proteus Effect is the phenomenon by which users infer their expected behaviors and attitudes from observing their avatar's appearance (Yee and Bailenson 2007; Yee, Bailenson, and Ducheneaut 2009). This effect occurs because specific characteristics of a character, such as height, skin color, gender, or attractiveness, are associated with specific types of behavior. These effects may transfer into real-world behavior. For example, Yee, Bailenson, and Ducheneaut (2009) found that people embodying a taller avatar in VR negotiated more aggressively in subsequent face-to-face interactions than participants given shorter avatars. Rosenberg, Baughman, and Bailenson (2013) found that participants embodying an avatar with the superhero ability to fly engaged in increased helping behavior in the real world immediately after the experiment, compared to participants in the control condition who were passengers in a virtual helicopter. Virtual embodiment also offers possibilities in the context of rehabilitation.

A. Domestic Violence and Future Selves

Several studies conducted among domestic violence offenders illustrate the possibilities of virtual embodiment to increase perspective taking. Seinfeld and colleagues (2018), for example, investigated how male perpetrators of domestic violence themselves experienced a scene of domestic violence from the perspective of a female victim. The participants' bodies

were replaced by a virtual female substitute that moved synchronously to their own. In other words, the researchers created a full body ownership illusion that allowed the participating male offenders to be in the body of a female victim of domestic abuse. Participants' emotion recognition skills were assessed before and after the virtual experience. As expected, compared to controls the offenders had a significantly lower ability before the experiment to recognize fear in female faces. After being embodied as a female victim, offenders significantly improved their ability to recognize emotions, although their overall ability to recognize emotion was still reduced compared to controls.

Seinfeld et al. (2023) studied the experiences of male participants with a history of intimate partner violence and embodied them in a virtual child's body. Participants witnessed a domestic violence scene from a first-person child's perspective in which a male avatar verbally assaulted a female avatar. Males with a history of intimate partner violence showed an increase in their sensitivity to recognize emotions (anger and, to a lesser extent, fear) in female faces. Additionally, males with a history of partner violence showed larger physiological responses during an explicit violent occurrence in the virtual scenario compared with controls, while their physiological reactions were less pronounced when the virtual abuser invaded the victim's personal space. Both groups reported that the VR experience helped them better understand how a child feels under this type of violent situation.

The illusion of virtual embodiment could be a useful tool for rehabilitating young offenders. Paternoster and Bushway (2009, p. 1113) argue that "in addition to a sense of who and what one is at the moment (a self that is fixed on the present), an individual also has a sense of self that is directed toward the future." Desistance from crime is assumed to require a fundamental shift in the individual's sense of self, that is, a transformation of one's identity (Maruna 2001; Paternoster and Bushway 2009).

An illustration of how VR offers new possibilities to trigger such changes in a way that is difficult, if not impossible, to achieve with other methods is provided by van Gelder, Hershfield, and Nordgren (2013). This study, which was conducted among university students, builds on the well-established idea that the tendency to live in the here and now, and the failure to think ahead, is one of the strongest individual-level correlates of delinquency. In the experimental condition of this study, aged visual analogs (i.e., avatars) of participants were created in order to have participants

"meet" their future selves in an immersive VE. For control participants, a present self avatar was created. Participants walked around in a virtual room and were confronted with their future self (and controls with their present self) when looking into a virtual mirror hanging in the room. Subsequently, they had the chance to steal money in the real world. Participants who had interacted with a digital version of their future, age-progressed, self in the VE were significantly less likely to steal compared to controls.

This finding was conceptually replicated by van Gelder, Cornet, et al. (2022) among a sample of actual offenders. Convicted offenders placed under supervision of the Dutch Probation Service interacted with their future self who was seated on the other side of a table in a virtual room (see fig. 4). During the interaction, they also swapped virtual bodies so that participants "became" their future self and now faced their present self. The participants asked their future self prescripted questions pertaining to their (actual) lifestyle and answered these questions while embodying their future self avatar. The interaction concluded with advice the participants embodied as their future self gave to their present self. Participants self-reported their delinquent and self-defeating behavior (e.g., alcohol and substance use) over the preceding 7 days before the experiment and once again 7 days afterward. The drop in self-defeating behavior from before to after the experiment was associated with simultaneous increases in vividness of the future self, suggesting that the more vivid image of the future self these offenders developed explains the reduction in their delinquent behavior.

V. Limitations

Thus far, I have focused primarily on current and future possibilities of VR, but the technology is not a panacea and prone to its own series of limitations. In this section, I briefly discuss ethical and privacy concerns, physical discomfort that may be experienced when using VR equipment, hardware limitations, and cost.

A. Ethical and Privacy Concerns

The first, and arguably most important, challenge in using VR for research purposes relates to ethical and privacy concerns. As technology tends to develop faster than regulatory frameworks guiding its use, researchers need to tread with caution and act responsibly to protect its

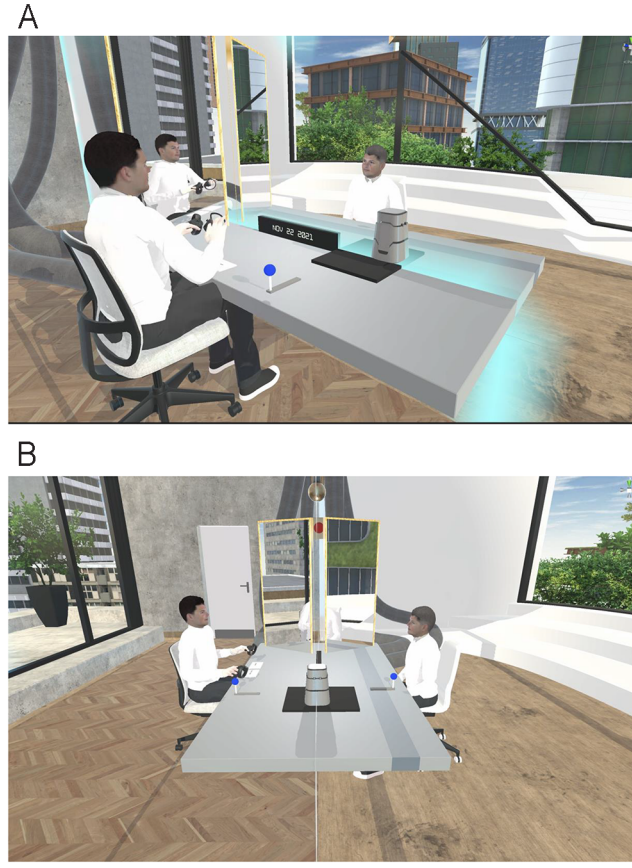

FIG. 4.—Impressions of the virtual reality environment used in van Gelder, Cornet, et al. (2022). Present self (*left avatar*) interacts with his future self (*right avatar*). Color version available as an online enhancement.

users. VR is no exception to this. Below, I highlight several ethical considerations and concerns in the research domain.[7]

VR systems allow unobtrusive and continuous collection of data, including biometric data, in multiple ways. It is, and will continue to be, essential that researchers understand critical complexities surrounding digital security of VR and ensure that sensitive data are not accessible to

[7] Risks and ethical considerations for private consumers of the technology raise similar and different issues (see Madary and Metzinger [2016], Bailenson [2018*b*], and Slater et al. [2020] for more extended discussions).

third parties. Recent research shows that users of VR may be identifiable on the basis of their tracking data. Miller and colleagues (2020) report that a simple machine learning model, using only position tracking data, was able identify people in a sample of more than 500 participants with more than 95 percent accuracy using less than 5 minutes of tracking data.

The privacy policies governing popular VR goggles, such as the Oculus goggles, which are developed and owned by Facebook's parent company, Meta, state that the company is permitted to share any de-identified data. However, this raises troubling concerns if tracking data are subsumed within de-identified data when they can be personally identifying (Miller et al. 2020). User behavior in VR may reveal mental processes and conditions that users may not want to share with third parties. Researchers, therefore, need to be well aware of such data sharing and ensure its avoidance (e.g., by disconnecting their VR hardware from the internet during data collection).

The ability of VR to mine troves of data from users raises a major ethical issue from a privacy perspective, but from a research standpoint, Yaremych and Persky (2019) note, it also highlights the value inherent in the behavioral data collected by VR systems. It is crucial therefore that researchers employ robust frameworks concerning consent, privacy, and security and consider and mitigate potential risks before collecting data. To this end, Madary and Metzinger (2016) developed a VR code of conduct containing principles for good scientific practice.

Another, and related, ethical concern regards the use of VR among vulnerable populations, such as incarcerated offenders and (young) delinquents. Ligthart and colleagues (2022) note that in forensic psychiatric settings, in contrast to regular health care settings, VR interventions may be offered not only for health care purposes but also for security reasons. Although offenders formally retain the choice not to participate, their degrees of freedom may be limited, for example, if consideration for parole is conditional on participation (Ligthart et al. 2022).

Yet, as it is also clear that VR can have a positive impact on the well-being of its users, helping them to control impulses, prepare for life outside prison, and strengthen a sense of moral agency and autonomy, the technology should not be withheld. Researchers should exercise caution and pursue user-centered instead of technology-driven approaches and ideally involve people with pertinent lived experiences in the design process

(Teng and Gordon 2021). There is an additional burden on researchers here as the unfamiliarity and complexity of the technology may require effort to clarify what research participants are actually consenting to.

B. Sickness, Nausea, Eye Strain

The continuous flow of data running from the computer to the user and (near) real-time updating of immersive VR systems generates a naturalistic or intuitive viewing experience that mimics critical properties of the real-world viewing experience (Pan and Hamilton 2018). Flaws in this process can cause nausea and an experience known as "cybersickness." Cybersickness describes physical unease that can be experienced due to discrepancies between the internal expectations of the user and the actual VR feedback, for example, a delay between the user's head movement and the visual feedback from the VR. Symptoms can include motion sickness, ocular strain, and degraded limb and postural control (Schuemie et al. 2001).

Cybersickness is dependent on a number of factors, including the hardware and software used and properties related to the individual. For example, ill-conceived VEs, low refresh rates due to slow hardware, and a user's susceptibility to motion sickness may each affect the experience in a negative way (Cornet and van Gelder 2023). Improvements in VR hardware have reduced the frequency of occurrence of these discomforts but have not entirely resolved them.

C. Generalizability

In spite of its name, virtual reality is not reality.[8] Although tremendous progress in realism over the years has been realized, VR is still easily identified as artificial. This may not be problematic per se. In a research context, realism is defined by not only visual fidelity but also psychological fidelity: the extent to which stimulus presentation evokes the type of physiological or emotional response one would experience in real life. In other words, the sensory input of a VE should approximate that of its real-life equivalent. Research should thus focus on the latter and not waste time attempting to perfect visual realism.

There is an interesting parallel between VR and flight simulators in this respect. Caro (1988) notes that it was long assumed that the degree

[8] In this sense, the term virtual reality is a bit of a misnomer, and immersive virtual environments would, e.g., be a more appropriate label.

of realism of a simulator was critical to ensuring the transfer of acquired skills from training to flying an actual plane. However, for most procedural tasks, training in low-realism simulators (e.g., made of plywood, dowel rods, and photographs), pilots performed equally well in actual aircraft as pilots trained in the much costlier high-realism simulators or even in aircraft.

That said, despite promising findings, what participants do in VR does not necessarily match how they behave in real life. Generalizability of findings is, therefore, not a given and will be contingent on many factors.[9] As Pan and Hamilton (2018) note, just as we do not always know whether the findings of laboratory studies apply in the real world, we must be cautious about claiming that VR studies, in which participants know they are participating in an experiment, generalize to real-world interactions. Several studies have demonstrated correspondence between behavior in the virtual world and in the real world (e.g., Slater et al. 2006; Nee et al. 2015, 2019), but more research is necessary to examine to what extent these findings hold over different situations, under what conditions, and among different populations. Going forward, improving our understanding of the extent to which VR findings in criminological research generalize to other contexts and establishing boundary conditions of VR research paradigms will be imperative.

D. Other Limitations

Although the development of VR has progressed tremendously, especially in the last decade, VR hardware has limitations. The resolution of VR displays, for example, is still relatively low compared to standard computer screens. Thus it does not support studies that require high-fidelity graphics, such as subtle emotional expressions (Pan and Hamilton 2018). Furthermore, although VR headsets have evolved from large, heavy, and clunky devices to more proportional tools, they may not feel comfortable still, particularly when longer periods of time are spent in VR.

[9] Rovira and colleagues (2009, p. 3) mention three aspects required for participants to consider VR plausible: first, participant actions are correlated with reactions within the virtual world, such as when a participant stares at a virtual character who as a result stares back. Second, aspects of the environment should contingently refer directly to the participant. For example, a character spontaneously speaks to the participant in a way that unambiguously signals the presence of the participant to the character. Third, when the scenario depicts events that could happen in physical reality, they should unfold according to the knowledge and prior expectations of the participant.

Furthermore, VR is extremely data intensive and simultaneously collects multiple streams of data. The necessity to reduce these data to a manageable and interpretable form can be complex and challenging, and adding new features (e.g., multiuser VR, facial expression recognition) will multiply these data streams (Yaremych and Persky 2019). Current tracing measures typically fail to integrate these multiple data sources into a cohesive picture of the user's behavior as time unfolds. However, commercial software packages are increasingly becoming available to deal with (continuous) data coming from different sources.

E. Cost

Along with significantly improved capabilities, comfort, and user friendliness, costs of VR equipment have dropped dramatically. On the hardware side, off-the-shelf and highly functional equipment, such as low-cost headsets (costing mere hundreds of euros/dollars) and affordable computers with ever more processing power, has greatly increased the accessibility of VR. As price points are an important factor driving adoption, this development can be expected to contribute to the further uptake of VR in the research community.

Compared to hardware, developing customized VR software is generally costlier unless it can be developed in-house (e.g., in collaboration with a university's computer science department or with computer scientists elsewhere) or when existing VEs can be used. Open-source VEs and user tutorials of programs such as the Unity Engine allow for basic, but functional, environments that could potentially be used for pilot studies.

Because developing VEs often requires a specific skill set not commonly found in social and behavioral science departments, in-house development is typically beyond the scope of the average research department. However, VEs are scalable, can be reused, and are also easily shared between researchers. Hence departments may, for example, pool resources to codevelop VEs to address research questions of common interest. That is, single environments can serve to answer multiple research questions, potentially without or with only modest iterations. Think, for example, of a barroom or other nightlife venue to study aggressive behavior (see van Gelder et al. 2019; van Gelder, De Vries, et al. 2022), a generic public area to examine the effects of peers on delinquency, a disorganized neighborhood or street segment to study the effect of disorder, embodied versions of economic games (see van Loon et al. 2018), or moral decision-making dilemmas such as the Trolley Problem (Navarrete et al. 2012; Francis et al.

2017). These are just a few examples of specific types of environments that are likely to be of interest to a wider range of researchers and that can be used for multiple studies or even form the basis of entire research programs.

The possibility of shared VEs is important not only to reduce costs or to set up research collaborations but also because it allows for the replication of research findings. In a time in which open science is becoming increasingly the norm, and ideally will become standard research practice in criminology, VR technology can contribute to this aspiration. Additionally, shared environments can also contribute to a certain degree of standardization that may benefit the field in the longer run, for example, in terms of comparability of research findings.

Before embarking on the development of VEs to study research questions, researchers should inform themselves about the technology and ask critical questions regarding cost effectiveness, feasibility, whether the research goal can also be achieved using real-world stimuli, and whether paper-based or in-person programs or approaches are possible, acceptable, or perhaps even preferable alternatives. For example, written scenarios are typically developed within a matter of hours and do not carry material costs and in certain cases may be fit for purpose. For example, VR, at least in its current form, may be unnecessary and unlikely to outperform conventional methods for studying types of crime such as white-collar crime, embezzlement, or tax fraud that do not involve much overt behavior or interaction.

VI. Concluding Remarks

Over the course of its history, mainstream criminology has largely focused on properties of offenders and the factors that propel them into and out of crime—such as the pressures that impel them to transgress, circumstances that predict delinquent involvement, turning points that may be critical for continuing and terminating a criminal career, and the socially acquired norms that facilitate rule breaking. Factors that play a role during the crime event and human agency have received far less attention, and for good reason: much of the behavior of interest to criminologists is beyond the purview of the research methods in the criminologist's toolkit.

In this essay, I have described how the use of VR may address the skew in the current knowledge base and how the technology can overcome some of the practical, methodological, and ethical challenges traditionally involved in crime research. The merits of VR for research purposes, such

as its ability to achieve high levels of ecological validity without compromising internal validity, how it can both induce emotional and affective states and measure such states, reproducibility, and the real-time observation of behavior, have been realized, described, and capitalized on by researchers across the behavioral sciences in the past decades. Criminologists have yet to seize this opportunity, particularly given the unique benefits that immersive technologies afford this field in terms of allowing the study of criminal events as they unfold and observing and measuring behavior in highly detailed and multifaceted ways. As the technology is still developing and its use in criminology is in its infancy—most VR experiences are still quite limited—current research offers only a hint of its full potential. Within the foreseeable future, however, VR may become the criminological equivalent of the petri dish, offering the possibility to study the unfolding of highly complex behavioral processes in very detailed ways and helping to achieve step changes in our understanding of crime.

In closing, I offer a brief note on theoretical relevance. This essay was primarily written as a methodological treatise detailing the benefits, possibilities, and limitations of VR for criminologists. However, as research methods, technology, and theory tend to be intimately related, the adoption of VR as a research tool in criminology will also carry theoretical implications. The preponderance of panel studies and advances in statistical modeling and survey methods, which were enabled by the increased availability of ever-more-powerful personal computers and exponential increases in computer processor speed, have led to a shift from a theoretical view of crime as a consequence of complex social processes to a more impoverished variable-based conception (Pratt and Turanovic 2011). The application of VR technology, if taken up by the criminological community at sufficient scale, and its ability to look straight into the black box may therefore have a profound influence on not only how we study crime but also how we conceive of its nature. It will be exciting to observe how VR-based process approaches in the future will lead to novel insights in our understanding of crime.

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