Virtual reality suicide: Development of a translational approach for studying suicide causes☆

Joseph C. Franklin*, Xieyining Huang, Diana Bastidas

Florida State University, United States

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ABSTRACT

Causal knowledge is crucial for understanding and preventing suicide. Unfortunately, we have little direct knowledge about suicide causes because we cannot conduct experiments that seek to make suicide more likely. In such situations, translational approaches can provide valuable, though tentative, information. We sought to establish a new translational approach by developing a laboratory approximation of suicide with new virtual reality (VR) technologies. Such an approach would allow researchers to tentatively investigate the causes of suicide by conducting experiments that introduce purported causes of suicide and observe their effects on VR suicide rates. Across three studies (total N = 498), results indicated that our two VR suicide scenarios (jumping from heights; shooting oneself) were safe; rated as unpleasant, realistic, and suicide-relevant; associated with several relevant predictors of VR suicide completion, including male sex, suicidal desire, suicidal capability, agitation, and prior suicidality; associated with reasons for *not* engaging in VR suicide that are similar to the reasons people give for *not* engaging in actual suicide; and produced 5% completion rates under neutral conditions and 25% completion rates after reward/avoid manipulations. We hope that future work further improves this approach and applies it to more directly test ideas about suicide causes and suicide prevention.

1. Introduction

Suicide is one of the greatest mysteries of human behavior. At first glance, suicide would seem impossible because it appears to run directly counter to perhaps the most fundamental instinct of all life: to survive. Yet suicide is relatively common, accounting for approximately 1.5% of all deaths (World Health Organization, 2017), making it a leading cause of death that claims nearly 800,000 lives worldwide each year. The devastation and prevalence of this counterintuitive behavior has led many to theorize about the causes of suicidal behaviors. That is, many have theorized about the factors that, when manipulated, make suicidal behaviors more likely (cf. Kraemer et al., 1997). After over one hundred years of theories, however, there is little consensus on the causes of suicidal behaviors. In fact, consensus may be diminishing as new theories are introduced each year while older theories persist. This has many downstream effects, including making it difficult to formulate effective suicide interventions – without firm knowledge about what causes suicidal behaviors, it is hard to know which causal processes to interrupt to prevent suicidal behaviors. So why is there little consensus on the causes of suicidal behaviors?

One major reason is that suicide research is at an inherent disadvantage compared to many other fields. The phenomenon of interest – suicide – cannot be used as an outcome variable in experiments that seek to make suicidal behavior more likely (cf. Nock, 2012). In other words, we cannot directly and systematically study the causes of suicide. In such situations, a translational approach is helpful (see Woolf, 2008). Within this approach, basic mechanisms are studied by testing laboratory approximations of the phenomena (e.g., cellular models, animal models, behavioral analogs in humans). This allows for the phenomenon to be studied safely and in a highly controlled manner, which allows for causal inferences that otherwise could not be made (Campbell & Stanley, 1963; see; Franklin, Huang, Fox, & Ribeiro, 2018). The tradeoffs are that only an approximation of the phenomenon is studied, and the tight experimental designs may reduce ecological validity. But especially when considered in conjunction with other lines of evidence (e.g., theory, self-report, longitudinal evidence), these laboratory studies can produce excellent candidates for further study within more real-world settings. In other words, knowledge from these basic laboratory studies can later be *translated* to the actual phenomenon of interest. Such translations are typically imperfect, but they are often useful.

Translational approaches are popular in medical science, clinical

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psychology and psychiatry, and even basic psychological science. Indeed, most laboratory tasks in psychology could be considered imperfect approximations of a given phenomenon that are then translated (or assumed to translate) to the actual phenomenon (e.g., prisoner's dilemma games). Given suicide's extreme nature, however, laboratory approximations have not been a major part of the suicide research tradition. Recently, this has begun to change, with an emphasis on animal models relevant to suicidal behavior (Gould et al., 2017) and laboratory tasks involving pain, distress, and behavioral measures (e.g., Anestis & Capron, 2016). We hoped to add to this work by taking advantage of new virtual reality (VR) technologies to develop a potentially useful new translational approach for the study of suicide causes.

These new VR technologies have high definition visual and audio capabilities, room-scale tracking (i.e., movement in actual and virtual environments is synchronous over a 15 ft × 15 ft area), and a large number of established scenarios that can be repurposed to mimic suicidal situations and behaviors. Moreover, these technologies are relatively affordable, with an entire state-of-the-art system (i.e., headset, base stations, controllers, computer with high-end graphics card) currently costing approximately $2000. This affordability means that a large number of labs may be able to use this approach to test ideas about suicide causes. Like most other laboratory approximations, however, we emphasize that this approach necessarily will have limited ecological validity and (thankfully) cannot capture all facets of suicide (e.g., actual death). But, as with other laboratory tasks throughout psychology, we reason that this approach may be able to approximate suicide well enough to permit tentative tests of causal hypotheses about suicide that can later be translated into real-world tests of these hypotheses.

The primary goal of the present series of studies is to attempt to establish two VR suicide scenarios that can be used as outcome variables in experiments. These three studies represent only the initial steps toward this goal. With VR technologies advancing each year, more studies testing additional aspects of these scenarios, and other researchers developing better scenarios, we believe that this approach can continually improve. We hope that the present series of studies will serve as a foundation for these improvements, ultimately culminating in a viable laboratory-based approach to studying suicide causes.

2. Study 1

We had four goals for our first study in this development process. First, we sought to determine if a VR suicide approach was feasible in terms of logistics and safety. For logistics, this meant locating two existing and widely available VR scenarios and repurposing them as VR suicide scenarios. For safety, we evaluated whether participants would become nauseous during the scenarios, refuse to participate in the study given its nature, or display increased suicidal thoughts, capability, implicit associations with death/suicide, and suicide risk as a result of VR suicide scenario exposure. Second, we examined whether these two VR suicide scenarios were associated with what we assume are the modal affective correlates of being in a suicidal situation (there are no *in vivo* studies of this for direct empirical comparison). Specifically, compared to control scenarios, we expected VR suicide scenarios to be associated with higher negative affect and lower positive affect. Third, we were curious if the percentage of participants who completed VR suicide (i.e., went through with the instructed virtual suicidal behavior) would roughly approximate that of actual suicidal behaviors in a general population sample. We reasoned that, ideally, rates would be low enough to roughly approximate the rates of suicidal behaviors in a general sample (~5–15%), but not so low that studies would require thousands of participants to examine differences between VR suicide completers and non-completers (~1–2%). Fourth, we explored a few potential correlates of VR suicide completion, including sex, self-criticism, the degree to which participants felt compelled to obey researcher instructions to engage in VR suicide, and experience with video games

and VR.

3. Methods

3.1. Participants

Participants were 287 undergraduate university students (189 females, 65.85%; 98 males, 34.15%) recruited from Psychology courses for research participation credit. The average age was 18.81 (*SD* = 2.05), and 200 participants self-identified as White/Caucasian (69.69%), 45 as Hispanic/Latino (15.68%), 30 as Black/African-American (10.45%), 9 as Asian/Asian-American (3.14%), and 2 as Mixed Ethnicities (0.70%). Participants were randomly assigned to receive either VR suicide scenarios (*n* = 148) or control VR scenarios (*n* = 139).

3.2. Procedure

Upon arriving at the laboratory, all participants completed the following procedural steps: (1) Read and signed an informed consent form; (2) received an orientation to the VR room, headset, and controllers, and were outfitted with the headset and controllers; (3) underwent a neutral VR scenario designed to orient them to VR and to following experimenter instructions while in VR (see Supplementary Methods S1 for more information on specific study instructions); (4) received their first VR scenario, which differed based on group (i.e., only the VR suicide group received VR suicide scenarios) and time point (each participant received either two VR suicide scenarios or two control VR scenarios, order was counterbalanced across participants); (5) completed ratings of how they felt during the just-completed VR scenario and several safety-related measures; (6) underwent their second VR scenario and completed ratings of how they felt during the just-completed VR scenario and one safety-related measure; (7) completed a battery of questionnaires assessing demographics and potential correlates of VR suicide; (8) underwent a positive mood induction; (9) received a suicide risk assessment (i.e., a full empirically-informed suicide risk assessment; see Chu et al., 2015 and Supplementary Methods 2 for more information on this protocol); and (10) were debriefed and compensated. Across all studies, participants were informed about the general procedure described above before participating, but not explicitly informed about the relevance of the study to suicidality. However, this relevance was described and discussed during the debriefing phase of each study. All procedures in all studies were approved by the Florida State University IRB.

3.3. VR scenarios

Each VR scenario lasted approximately three minutes. Due to space limitations, please see Supplementary Methods S1 under section Study 1 for specific details on the scenarios, where to find them online, and the exact instructions used. One notable aspect of Study 1 instructions is that participants were allowed to ignore any instructions (e.g., to engage in VR suicide), but they were not given any explicit behavioral alternatives to VR suicide. Below, we provide a brief overview of the scenarios used in the present study.

Orientation scenario. All participants received an orientation scenario as a way to familiarize participants with VR and following experimenter instructions while in VR. Without this orientation, participants in early piloting tended to become absorbed by the novelty of VR and wandered around without respect to experimenter instructions.

Control scenario: Intro the VR. Intro to VR is a free app that cycles through several interesting scenes over the course of approximately three minutes (e.g., space, a group of elephants, Cirque du Soleil). These scenes primarily consistent of real-world video.

Control scenario: Quill VR. Quill VR is a free interactive art app that allows users to draw and animate in three-dimensional VR space.

VR suicide scenario: Jumping. There are several VR scenarios that involved jumping from a high place, but we chose an app called Richie's Plank Experience ($15) because of its high quality visual, auditory, and spatial qualities. It also has an open-world quality, meaning that the user can proceed as they desire (vs. being forced through a pre-determined sequence of events), which is necessary for participant-determined behavior. In this scenario, participants appeared on a virtual street in a city, entered an elevator, went up a few hundred feet, and watched as elevator doors opened to a plank extending out over a ledge. Participants were instructed to walk out onto this plank and to step off of it to plummet to ground below. If they chose to step off the plank, participants virtually fell to the ground below and, upon reaching the ground, the screen faded to white and the scenario ended for the participant.

VR suicide scenario: shooting. There are a large number of VR shooting scenarios that could be repurposed as VR suicide scenarios. For this study, we chose an app called Cockroach VR because of its ease of use, open-world nature, and low cost ($2). Although we believed that some other programs had slightly higher quality graphics, these other programs were typically far more expensive and difficult to use (e.g., take several minutes to setup, complicated gun operation). In this scenario, participants appeared in an apartment with a gun in their hand, faced a wall, and were instructed to point the gun toward their faces and pull the trigger. Upon pulling the trigger, the gun made a loud noise, produced a muzzle flash, and the scenario ended for the participant.

VR positive mood induction. As a positive mood induction, we used an immersive, animated short VR film called The Rose and I ($5). It is a warm and comical tale of a child becoming friends with a rose.

3.4. VR equipment

We used the two highest-quality commercially available VR systems for the present study: Oculus Rift and the HTC Vive. These two systems are largely interchangeable, with the HTC Vive holding a slight advantage in terms of tracking area. The Oculus Rift was released in 2016 and includes a headset, headphones that provide three-dimensional sound, controllers, and base stations that provide room-scale positional tracking. The headset has a PenTile OLED display, 110-degree field of view, 1080×1200 pixel resolution per eye, and a 90Hz refresh rate. The HTC Vive was also released in 2016 and has hardware specifications identical to those just noted for the Oculus Rift, but with slightly different software and a larger tracking area. We used the Oculus Rift for control scenarios and the positive mood induction (at the time, these scenarios could only be experienced via Oculus Rift), and we used the HTC Vive for the VR suicide scenarios.

The Oculus Rift and HTC Vive systems were run from MSI Vortex G65VR SLI-096 computers, with NVIDIA GeForce GTX 1070 graphics cards, 256 GB SSDs, 32 GB RAMs, and an Intel Core i7 CPUs. These specifications are all above the recommended specifications for the Rift and Vive (i.e., GTX 1060 graphics card; 4 GB RAM; Intel Core i5 CPU). The VR space was an empty 15 ft $\times$ 30 ft room within our laboratory (the VR computers were located in separate, adjacent rooms).

3.5. Questionnaires

Due to space limitations, detailed information about questionnaires is included in Supplementary Methods S2. Below, we provide a brief overview of the measures used in the present study.

Demographics questionnaire. This questionnaire assessed sex, age, and ethnicity.

Safety-related measures. We administered a range of measures after the first VR scenario to experimentally test the effects of VR suicide scenario exposure (vs. control VR scenario exposure) on several questions related to suicide ideation and capability, implicit associations with death/suicide, and implicit affect toward the self, others, self-

injury, and death/suicide. We administered the suicide-related questions again after the second VR scenarios. At the end of the study, we conducted risk assessments to ensure safety and to quantify the experimental effects of VR suicide exposure on suicide risk. See Supplementary Methods S2 for detailed information about these measures.

Positive and Negative Affect Schedule (PANAS; Watson & Clark, 1999*).* The PANAS is a commonly used measure to assess momentary experiences of positive and negative affect. All items were scored on a 0 (not at all) to 4 (extremely) scale.

Self-Ratings Scale (SRS; Hooley, Ho, Slater, & Lockshin, 2010*).* The SRS assesses self-critical beliefs.

Gaming experience. To assess whether gaming and VR experience had any bearing on results, we included items that inquired about prior experience with video games in general and VR in particular.

Obedience to experimental instructions. To determine the degree to which obedience to instructions influenced VR suicide completion, we asked participants about (1) their comfort with notifying the experimenter that they would like to stop the study; and (2) the degree to which they felt compelled to follow study instructions. These items were rated on a 0 (not at all) to 10 (extremely) scale.

3.6. Data analytic plan

We used one-sample *t*-tests to examine whether realism, positive affect, and negative affect values were significantly different from zero. We then conducted independent-groups *t*-tests to examine potential differences between the VR suicide and control VR groups on these three variables. Realism analyses were two-tailed, and the other two analyses were one-tailed (hypothesizing lower positive affect and higher negative affect in the VR suicide group). We then used dependent-groups *t*-tests to test for differences between the ratings across participants' first and second scenarios and across shooting and jumping scenarios (two-tailed). Across studies, participants were allowed to omit answers to any questions, but data were missing less than 0.5% of the time and all data were missing at random according to Little's Missing Completely at Random test (all *p*s > 0.75). There were no missing data for VR suicide completion/non-completion analyses.

For VR suicide completion rates, we tabulated the proportion of times participants engaged in VR suicide overall (i.e., completions/ opportunities), across each administration, and across the jumping and shooting scenarios. We also calculated the proportion of participants who engaged in VR suicide at least once. Potential correlates were tested by using one-tailed Student's *t*-tests to compare VR suicide completers (i.e., those who engaged in VR suicide at least once) to non-completers. Alpha was set at 0.05 for all analyses.

4. Results

4.1. Safety and logistics

In terms of safety, no participants reported nausea or distress, no participants refused to participate in the study, and no participants indicated suicide risk when assessed at the end of the study session. As detailed in Supplementary Tables S1–S3, there were no significant effects of VR suicide scenario exposure (compared to control VR exposure) on any safety-related measure, including questions assessing suicide ideation, desire, and capability; implicit associations with death/suicide; implicit affect toward death/suicide; and suicide risk level as formally assessed at the end of the study session (all *p*s > 0.15). In terms of logistics, all equipment ran smoothly throughout the study and we were able to locate two established VR scenarios that could be repurposed as VR suicide scenarios (see Supplementary Methods S1). These scenarios are accessible to anyone with internet access and were low cost. In sum, this approach seems to be feasible in terms of both general safety and logistics.

Table 1

Affect, realism, and suicide-relevance across studies. *Notes.* All measures were on a 0 (low) to 4 (extreme) scale. "Overall" tests were One-Sample *t*-tests; Control Group vs. VR Suicide Group tests were Independent-Groups *t*-tests (Study 1); all others were Dependent Sample *t*-tests. These findings indicate that VR suicide scenarios are associated with significantly greater negative affect and significantly lower positive affect compared to control VR scenarios (Study 1); moderate mean levels of realism and suicide-relevance (Studies 1, 2, 3); and consistency across the first and second administrations of VR suicide scenarios.

Groups/Scenarios	Study 1 (Control N = 139; VR Suicide N = 148)	
	Positive Affect Mean (SD)	Negative Affect Mean (SD)
Control Group Overall	2.09 (0.93)	0.33 (0.43)
VR Suicide Group Overall	0.72 (0.80)	1.46 (0.98)
Tests	*t*(283) = 13.42, *p* < .001	*t*(283) = −12.52, *p* < .001
First Scenario (Both Groups)	1.50 (1.25)	0.90 (1.00)
Second Scenario (Both Groups)	1.26 (1.30)	0.92 (1.12)
Tests	*t*(284) = 3.23, *p* = .001	*t*(284) = −0.41, *p* = .68
Shooting Scenario (VR Sui Group)	0.49 (0.81)	1.25 (1.05)
Jumping Scenario (VR Sui Group)	0.94 (1.07)	1.67 (1.20)
Tests	*t*(146) = −5.27, *p* < .001	*t*(146) = −4.66, *p* < .001
	Realism Mean (SD)	
Shooting Scenario (VR Sui Group)	1.76 (1.30)	
Jumping Scenario (VR Sui Group)	2.32 (1.25)	
Tests	*t*(145) = −6.13, *p* < .001	
Scenarios	**Study 2 (N = 179)**	
	Realism Mean (SD)	**Suicide-Relevance Mean (SD)**
Overall	2.62 (1.02)	2.42 (1.40)
Tests	*t*(176) = 34.36, *p* < .001	*t*(176) = 23.03, *p* < .001
First Scenario	2.49 (1.23)	2.44 (1.56)
Second Scenario	2.76 (1.17)	2.41 (1.69)
Tests	*t*(176) = −2.87, *p* = .005	*t*(176) = 0.23, *p* = .82
Shooting Scenario	2.54 (1.17)	2.07 (1.62)
Jumping Scenario	2.71 (1.24)	2.77 (1.55)
Tests	*t*(176) = −1.67, *p* = .10	*t*(176) = −6.12, *p* < .001
Scenarios	**Study 3 (N = 32)**	
	Realism Mean (SD)	**Suicide-Relevance Mean (SD)**
Overall	2.30 (1.09)	3.38 (1.02)
	t(31) = 11.90, *p* < .001	*t*(31) = 18.79, *p* < .001
First Scenario	2.03 (1.18)	3.28 (1.22)
Second Scenario	2.56 (1.16)	3.47 (0.98)
Tests	*t*(31) = −3.57, *p* = .001	*t*(31) = −1.18, *p* = .25
Shooting Scenario	2.09 (1.28)	3.41 (1.21)
Jumping Scenario	2.50 (1.08)	3.34 (1.00)
Tests	*t*(31) = −2.52, *p* = .02	*t*(31) = 0.39, *p* = .70

4.2. Experience of VR scenarios

All participants received either two VR suicide or two control VR scenarios.

Realism. As shown in Table 1, participants rated the VR suicide scenarios as moderately realistic, though the jumping scenario was rated as significantly more realistic than the shooting scenario.

Positive and negative affect ratings. Also as shown in Table 1, there were large differences in affective ratings between VR suicide scenarios and control VR scenarios. Specifically, participants rated themselves as feeling substantially more negative (*d* = 1.49) and less positive (*d* = 1.58) in the VR suicide scenarios compared to the control VR scenarios. Across both control and suicide groups, there was a slight but significant decline in positive affect from the first scenario to the second scenario, but no change in negative affect (see Table 1). Within the VR suicide scenarios, the shooting scenario was rated as significantly less positive and less negative compared to the jumping scenario (see Table 1).

4.3. VR suicide completion

Completion rates. The majority of participants in the VR suicide groups engaged in VR suicide (see Table 2). Rates were nearly identical from the first VR suicide scenario to the second (see Table 2), indicating that the present study found no evidence of a VR suicide training effect. More participants completed VR suicide in the jumping scenario compared to the shooting scenario. Half of participants engaged in VR suicide during both scenarios (Table 2).

Correlates of VR suicide completion. VR suicide completion was not significantly associated with demographics, experience with video games, experience with VR, or self-criticism (all *p*s > .05). Moreover, across both VR administrations, the completers (first: *M* = 8.07, *SD* = 2.68; second: *M* = 8.38, *SD* = 2.50), and non-completers (first: *M* = 7.48, *SD* = 3.06; second: *M* = 7.78, *SD* = 3.03) reported similarly high levels of comfort informing the researchers that they would like to cease study participation (*p*s = .30 and .25). Despite this, there was a strong obedience effect, such that there was a large difference between completers' and non-completers' reports of feeling compelled to follow research instructions to engage in VR suicide across both the first VR administration, *t*(146) = 6.37, *p* < .001, *d* = 1.26, and the second VR administration, *t*(146) = 3.40, *p* = .001, *d* = 0.73. Across both administrations, the completers (first: *M* = 7.31, *SD* = 2.81; second: *M* = 5.71, *SD* = 3.39) reported feeling more compelled compared to non-completers (first: *M* = 3.45, *SD* = 3.30; second: *M* = 3.31,

Table 2

VR suicide completion rates across studies. *Notes.* Studies differed by instruction type (i.e., non-choice or choice-based paradigms) and manipulations (i.e., no manipulation or a manipulation). Each participant underwent two VR suicide scenarios – a jumping scenario and a shooting scenario. The order of these scenarios was counterbalanced across participants. These data indicate that a choice-based paradigm is preferred because it generates very low VR suicide rates (Study 2 vs. Study 1), and that manipulations can affect the VR suicide rate in this paradigm (Study 3 vs. Study 2).

		Number of Participants Completing VR Suicide	Total Number of VR Suicide Opportunities Completed (2 Opportunities per Participant)
Study 1	*(No Choice Paradigm)*		
		N = 148 Participants	N = 296 Opportunities
	Either First or Second Scenario	115 (77.70%)	189 (63.85%)
	First Scenario	95 (64.19%)	
	Second Scenario	94 (63.51%)	
	Jumping Scenario	105 (70.95%)	
	Shooting Scenario	84 (56.76%)	
	Both Scenarios	74 (50%)	
Study 2	*(Choice Paradigm)*		
		N = 179 Participants	N = 358 Opportunities
	Either First or Second Scenario	17 (9.50%)	19 (5.31%)
	First Scenario	7 (3.91%)	
	Second Scenario	12 (6.70%)	
	Jumping Scenario	10 (5.59%)	
	Shooting Scenario	9 (5.03%)	
	Both Scenarios	2 (1.12%)	
Study 3	*(Choice & Manipulation Paradigm)*		
		N = 32 Participants	N = 64 Opportunities
	Either First or Second Scenario	10 (31.25%)	16 (25%)
	First Scenario	7 (21.88%)	
	Second Scenario	9 (28.13%)	
	Jumping Scenario	7 (21.88%)	
	Shooting Scenario	9 (28.13%)	
	Both Scenarios	6 (18.75%)	
	Reward Manipulation	5 (31.25%)	7 (21.88%)
	Avoid Manipulation	5 (31.25%)	9 (28.13%)

SD = 2.53). This obedience effect likely inflated the rates of VR suicide.

5. Study 1 discussion

The results of Study 1 were both encouraging and instructive. The VR suicide approach appeared to be feasible in terms of safety and logistics, and findings indicated that participants perceived all VR scenarios to be moderately realistic. Notably, the shooting scenario received lower realism ratings compared to the jumping scenario, suggesting that it may be helpful to consider repurposing a more realistic VR program for the shooting scenario. Consistent with expectations, results also revealed that, compared to control VR scenarios, VR suicide scenarios were associated with significantly higher ratings of negative affect and significantly lower positive affect.

Although the aforementioned results were promising, the VR suicide completion results indicated the need for a fundamental change to the approach used in the present study. Completion rates were far higher than ideal for a laboratory approximation of suicide (participants engaged in VR suicide on 63.85% of their opportunities). Our goal would be to have much lower completion rates, ideally with participants engaging in VR suicide on very few (i.e., 5%–15%) of their opportunities. This high completion rate seemed to be due to an obedience effect, whereby participants felt compelled to go through with VR suicide despite multiple notifications that there would be no penalty for ignoring instructions.

These findings were disappointing, but they were also highly instructive for future directions. Specifically, they indicated the need for a choice-based approach, wherein participants are given an explicit choice between completing VR suicide and engaging in a non-suicidal virtual behavior. This would likely reduce the obedience effect, possibly leading to a substantial reduction in VR suicide rates and improving the ability to observe correlates, predictors, and causes of VR suicide completion.

6. Study 2

We had four major goals for Study 2. First, we aimed to obtain similar realism to those observed in Study 1. Due to lower realism ratings for the VR shooting scenario in Study 1, we repurposed a more realistic-looking VR program for the shooting scenario in Study 2. In another variation on Study 1 protocol, we asked participants to rate the degree to which the VR scenario seemed suicide-related. We believed that this would be a direct gauge of participants' perceptions of the scenarios as relevant to suicide.

Second, based on the results of Study 1, we developed a choice-based approach for VR suicide and examined its effects on VR suicide completion rates. We expected this change to substantially reduce the VR suicide rate by lessening any obedience effects. Third, among participants who did *not* complete VR suicide, we investigated their reasons for non-completion. In particular, we were curious about the degree to which moral/religious reasons, identity-based reasons, and fear played a role in non-completion. As these are all general reasons that people give for not engaging in actual suicide (e.g., Linehan, Goodstein, Nielsen, & Chiles, 1983), we expected that they would be endorsed as reasons for not engaging in VR suicide. We were also curious if these participants could imagine any circumstances under which they would engage in VR suicide. We hypothesized that participants would indicate that there are few circumstances under which they could imagine ever engaging in VR suicide.

Fourth, we investigated several potential predictors of VR suicide completion, under the assumption that these predictors would resemble those of actual suicide. Accordingly, we measured variables *before* the VR portion of the study rather than *after* (as in Study 1). In keeping with the predictive magnitude of these factors for actual suicide (Franklin et al., 2017), we expected these effects to be small to moderate. Given the anticipated low levels and restricted ranges of many of these factors (e.g., prior suicide attempts, perceived burdensomeness) in this sample

of undergraduates, we reasoned these effects may be even smaller than typically observed in predictive studies. Overall, our aim for Study 2 was to build on Study 1 to establish a much better laboratory approximation of suicide.

7. Methods

7.1. Participants

Participants were 179 undergraduate university students (129 females, 72.07%; 50 males, 27.93%) recruited from Psychology courses for research participation credit. The average age was 19.64 ($SD = 1.28$), and 108 participants self-identified as White/Caucasian (60.34%), 40 as Hispanic/Latino (22.35%), 13 as Black/African-American (7.26%), 15 as Asian/Asian-American (8.38%), 2 as Mixed Ethnicities (1.12%), and 1 as Native American (0.56%).

7.2. Procedure, materials, and data analytic plan

The procedure of Study 2 was identical to that of Study 1, with three exceptions. First, because this study was a prediction study (vs. Study 1's controlled experiment), participants completed questionnaires immediately after they signed an informed consent form (vs. after their two VR scenarios). This change allowed us to test potential predictors (vs. correlates) of VR suicide. Second, because of the safety-related results of Study 1 and the fact that Study 2 did not include a non-suicide VR comparison group, we did not assess these measures in Study 2. Third, participants were given an explicit choice between a virtual suicidal behavior (jumping from a tall building; shooting oneself) and a non-suicidal behavior (pressing an elevator button to return safely to the ground floor of a tall building; shooting a blue barrel). See Supplementary Methods S1 under Section Study 2 for a transcript of these instructions.

We used the same orientation, VR suicide, and positive mood induction scenarios as in Study 1, with three exceptions. First, we used a more realistic app called Arizona Sunshine ($40) for the VR shooting scenario. Second, for the VR jumping scenario, there was no plank, just a ledge. We made this change because we were interested in whether participants would choose to fall to their virtual deaths (not whether they would walk out on a plank). We accordingly took advantage of the opportunity to remove the plank from the scenario, leaving only the ledge once the elevator doors opened. Third, we used slightly different instructions for this new choice-based approach (see Supplementary Methods S1 for more information on each of these points). VR equipment, computers, and laboratory space were identical to those used in Study 1.

Due to space limitations, please see Supplementary Methods S2 for detailed information about questionnaires used in this study. Below we provide a brief overview of these measures.

Repeat measures from Study 1. As in Study 1, we used the demographics questionnaire and the SRS to measure self-criticism. Similar to Study 1, we had participants rate the degree to which they felt the VR scenarios were realistic and suicide-related. These latter items were scored on a 0 (not at all) to 4 (extremely) scale.

Suicidal Capability. To gauge suicidal capability, we included the Fearlessness about Death scale (FAD; Ribeiro et al., 2014) and two additional items from the Beck Scale for Suicide Ideation (Beck, Steer, & Ranieri, 1988) that also reflected suicidal capability. The items were "*I have the courage and ability to commit suicide*" and "*I accept the idea of killing myself.*" Both of these items were significantly correlated with the FAD (see Supplementary Methods S2).

Suicidal desire. We used the Interpersonal Needs Questionnaire (Van Orden, Cukrowicz, Witte, & Joiner, 2012) to assess two theorized components of suicidal desire – thwarted belongingness and perceived burdensomeness. We additionally included two BSSI items that reflected suicidal desire, "*I have no desire to kill myself*," and "*I have a*

strong wish to die." Both of these items were significantly correlated with both INQ subscales (see Supplementary Methods S2).

Suicidal thought, plan, and attempt frequency. We used three ordinal items to assess the lifetime frequency of suicidal thoughts (21.3% of participants had at least one suicidal thought), plans (6.15% of participants had at least one suicide plan), and attempts (5% of participants had at least one suicide attempt). See Supplementary Methods S2 for more information.

Brief Agitation Measure (BAM; Ribeiro, Bender, Selby, Hames, & Joiner, 2011*).* The BAM is a scale that measures current levels of agitation.

Domain-Specific Risk-Taking scale (DOSPERT; Blais & Weber, 2006*).* The DOSPERT measures risk-taking propensity across five different domains.

Moral Orientation Scale (MOS; Fleischmann, Lammers, Conway, & Galinsky, 2019*).* The MOS indexes four different types of tendencies when making moral judgements. We hypothesized that a lower affective moral orientation would be associated with VR suicide, in part because this orientation could be construed as intersecting with some aspects of suicidal capability (e.g., less bothered by violations of social norms and the pain and injury of others). This subscale was significantly correlated with the FAD (Supplementary Methods S2).

Reasons for not engaging in VR suicide scale. We created this scale to measure potentially common reasons for not engaging in VR suicide. This included three general reasons (moral/religious, identity, fear) and an additional question about whether the participant could imagine any circumstances under which they would engage in VR suicide. The first three items were scored on a 0 (not at all) to 4 (extremely) scale; the last item was scored on a 0 (none) to 4 (many) scale. This scale was administered after each VR suicide scenario to those who did not complete VR suicide. For those who did not engage in VR suicide for either scenario, their responses were averaged across the two administrations.

We calculated the descriptive statistics for realism and suicide-relevance ratings, and then used two-tailed *t*-tests to examine overall differences and differences across each VR administration for the jumping and shooting scenarios. As in Study 1, we tabulated completion rates overall, across administrations, across scenarios, and among participants who engaged in VR suicide at least once. We then examined the descriptive statistics across each item of the *Reasons for not completing VR suicide* questionnaire. Finally, we analyzed the predictors of suicide completion. For most of the predictors, this involved one-tailed Student's independent-groups *t*-tests comparing the baseline predictors of the VR suicide completers (i.e., engaged in VR suicide at least once) and non-completers. Given the anticipated group imbalance for these analyses, any comparison that violated Levine's homogeneity of variance test was instead analyzed with a Welch's *t*-test. Due to their ordinal frequency nature, the three suicidality predictors were analyzed with one-sided linear-by-linear chi-square analyses. The alpha was 0.05 for all analyses.

8. Results

Realism and suicide-relevance. Overall, the two scenarios were rated as moderately realistic and suicide-relevant (see Table 1). Notably, the mode for suicide-relevance ratings was 4.0 (i.e., the highest possible rating) and the mode for realism ratings was 3.0 (i.e., the next-to-highest possible rating). Realism ratings increased slightly but significantly from the first to the second scenario, but there was no change in suicide-relevance ratings across administrations (see Table 1). Although both scenarios produced similar ratings, the jumping scenario again produced significantly higher realism and suicide-relevance ratings (see Table 1).

VR suicide completion rates. Rates of VR suicide were far lower compared to those observed in Study 1 (see Table 2). Rates were similar from the first to the second VR suicide administration, and rates were nearly identical across the jumping and shooting scenarios (see

Table 3

Predictors of VR suicide completion in Study 2. *Notes.* VR Suicide Non-Completers n = 162, VR Suicide Completers n = 17. Significant predictors are bolded. Each of the four item-based predictors violated the homogeneity of variance assumption for Student's *t*-test (Levine's test *p*s < .05), which is potentially problematic given the group sample size imbalance. In these four instances, we used Welch's *t*-test, which is robust against this assumption violation. This produced different degrees of freedom, *t*-values, and *p*-values compared to Student's *t*-test. All tests were one-tailed. For simplicity, Cohen's *d* figures are reported as absolute values. DOSPERT = The Domain-Specific Risk-Taking Scale for adults. These data suggest that the predictors of VR suicide within the choice-based paradigm may be similar in type, direction, and magnitude to those of actual suicide.

Predictors	VR Suicide Non-Completers		VR Suicide Completers		*t-value*	*p*-value	*Cohen's d*
	Mean	*SD*	*Mean*	*SD*			
Male (vs. female)	**1.76**	**0.43**	**1.35**	**0.49**	**t(177) = 3.66**	**< .001**	**0.89**
Fearlessness About Death Scale	**10.19**	**6.02**	**13.41**	**7.25**	**t(177) = -2.06**	**0.02**	**0.48**
item: "*I have the courage and ability to commit suicide*"	**0.14**	**0.40**	**0.76**	**0.66**	**t(17.24) = -3.79**	**0.001**	**1.14**
item: "*I accept the idea of killing myself*"	**0.14**	**0.48**	**0.41**	**0.62**	**t(18.12) = -1.74**	**0.04**	**0.49**
INQ Thwarted Belongingness	**10.80**	**8.76**	**16.71**	**10.82**	**t(177) = -2.58**	**0.01**	**0.60**
INQ Perceived Burdensomeness	1.83	3.88	2.71	3.92	t(177) = −0.89	0.19	0.23
item: "*I have no desire to kill myself*"	**3.66**	**0.90**	**2.94**	**1.43**	**t(17.35) = 2.03**	**0.03**	**0.60**
item: "*I have a strong wish to die*"	0.15	0.44	0.35	0.61	t(17.81) = −1.32	0.10	0.38
Brief Agitation Measure	**4.91**	**4.57**	**7.47**	**6.03**	**t(177) = -2.13**	**0.02**	**0.48**
Risk Taking (DOSPERT total)	**93.84**	**23.19**	**108.53**	**25.55**	**t(177) = -2.46**	**0.01**	**0.60**
Social Risk Taking	27.80	5.90	29.71	4.95	t(177) = −1.29	0.10	0.35
Ethical Risk Taking	**11.76**	**4.78**	**14.94**	**6.15**	**t(177) = -2.54**	**0.01**	**0.58**
Financial Risk Taking	**13.96**	**6.45**	**17.29**	**7.92**	**t(177) = -1.98**	**0.03**	**0.46**
Health/Safety Risk Taking	**17.63**	**7.21**	**21.18**	**6.17**	**t(177) = -1.95**	**0.03**	**0.53**
Recreational Risk Taking	22.70	9.26	25.41	9.78	t(177) = −1.14	0.13	0.28
Affective Moral Orientation	**36.98**	**8.22**	**31.53**	**6.71**	**t(177) = 2.64**	**0.004**	**0.73**
Deliberative Moral Orientation	36.69	6.00	35.88	7.43	t(177) = 0.52	0.30	0.12
Rule-Based Moral Orientation	25.78	7.14	24.12	6.54	t(177) = 0.92	0.18	0.24
Sentimental Moral Orientation	29.72	8.68	27.24	9.49	t(177) = 1.11	0.14	0.27
Self-Criticism	20.56	10.26	23.53	9.26	t(177) = −1.15	0.13	0.30

Table 2). Approximately 1% of participants completed VR suicide during both scenarios.

Reasons for not completing VR suicide. The most strongly endorsed item for not engaging in VR suicide was *Because I'm just not the kind of person who would ever choose the virtual suicide option* (*M* = 3.00, *SD* = 1.27, *Mode* = 4.00), followed by the *Because the virtual suicide option was just too scary* item (*M* = 2.25, *SD* = 1.38, *Mode* = 4.00) and the *Because of moral/religious reasons* item (*M* = 1.42, *SD* = 1.53, *Mode* = 0.00). In response to the item *Are there any circumstances under which you would choose the virtual suicide option?*, participants indicated that there were few such circumstances (*M* = 0.96, *SD* = 0.50, *Mode* = 0.00).

Predictors of VR suicide completion. As shown in Table 3, there were several significant predictors of VR suicide completion. These significant effects were moderate-to-large and spanned a range of predictor types (sex, suicidal capability, suicidal desire, prior suicidality, agitation, risk taking, and moral orientation). Nonsignificant predictors exhibited smaller effects (e.g., Cohen's *d*s ~ 0.30) in the expected directions (see Table 3). Although VR suicide completion was not significantly predicted by prior suicide ideation frequency (X^2[1]) = 1.12, *p* = .15), it was significantly predicted by the frequency of prior suicide plans (X^2[1] = 2.90, *p* = .04) and prior suicide attempts (X^2[1] = 3.09, *p* = .04).

9. Study 2 discussion

Study 2 produced several promising findings. First, results indicated that the participants regarded both VR scenarios as moderately realistic on average, with a modal rating of *quite a bit realistic*. The new shooting scenario was rated as nearly as realistic as the jumping scenario, suggesting that this new scenario was an improvement over the shooting scenario used in Study 1. Second, participants rated both scenarios as being suicide-related, with the modal participant rating these as *extremely suicide-related*. These findings are encouraging as they indicate that these two VR scenarios are generally regarded as both realistic and suicide-related.

Third, compared to Study 1, the VR suicide completion rates were

much more consistent with what one might expect from a laboratory approximation of suicide. Participants engaged in VR suicide on only 5.31% of their opportunities, with only 9.50% of participants engaging in VR suicide at least once. Only 1.12% of participants selected the VR suicide option in both scenarios. This dramatic VR suicide completion rate reduction indicates that the present choice-based VR suicide approach is superior to the instruction-based approach of Study 1.

Fourth, participants strongly endorsed identity-based and fear-based reasons for not choosing the VR suicide option, and few participants could imagine any circumstances under which they would engage in VR suicide. The modal participant endorsed the most extreme options available on these three questions. These findings indicate that, even though VR suicide is completely virtual, most participants regarded these virtual behaviors as too scary to engage in and did not see themselves as the kind of person who would ever engage in these virtual behaviors under any circumstances.

Fifth, the predictors of VR suicide resembled those of actual suicide. Males were 4.68 times more likely to engage in VR suicide compared to females, which approximates the 3.50 to 4.70 male-to-female suicide ratio observed in the United States from 1985 to 2015 (see Fox, Millner, Mukerji, & Nock, 2018). Although the rates of lifetime suicide plans and attempts were relatively low in this sample (~6% for plans, ~5% for attempts), these factors also significantly predicted VR suicide; future studies should more directly examine this potential association in larger and more severe samples. Factors related to suicide capability were among the strongest predictors of VR suicide, with the item *I have the courage and ability to kill myself* being the single strongest predictor (Cohen's *d* = 1.14). A lower affective moral orientation, which could be construed as being related to capability (e.g., lesser endorsement of items such as *I cringe when I see someone get injured*), was also a relatively strong predictor (Cohen's *d* = 0.73). Interestingly, thwarted belongingness was moderately predictive (Cohen's *d* = 0.60) and reached significance, whereas perceived burdensomeness was much weaker (Cohen's *d* = 0.23) and did not reach significance. This could be explained by the low levels and restricted range of perceived burdensomeness in the present sample. Other relevant factors, including agitation and risk taking, were also significant predictors of VR suicide. We

note here that, for clarity and space considerations, these predictive findings are presented in terms of *Cohen's d*. It is important to recognize, however, that even a relatively large *Cohen's d* corresponds with a relatively poor area under the receiver operating characteristic curve value (AUC; e.g., *d* = 0.70 [large effect] generally equates to AUC = 0.69 [poor accuracy]; see Rice & Harris, 2005). The magnitude of VR suicide predictors was accordingly similar to the magnitude of actual suicide predictors (cf. Franklin et al., 2017).

In sum, Study 2 provided evidence for a much better laboratory approximation of suicide compared to Study 1. In particular, the new choice-based approach greatly lowered the VR suicide completion rate and VR suicide completion was associated with a range of relevant predictors.

10. Study 3

Study 2 established a potentially workable laboratory approximation of suicide, but it did not evaluate whether this approach might be amenable to tests of causal ideas. That is, it did not test whether a systematic manipulation of a variable might cause a change in VR suicide completion rates. The primary purpose of Study 3 was to provide an initial proof-of-concept test of this possibility.

In this small (N = 32) proof-of-concept study, we tested whether two manipulations caused an increase in VR suicide completion rates: (1) an incentive for engaging in VR suicide (i.e., $20); and (2) a disincentive for *not* engaging in VR suicide (i.e., a stressful speech task). We do not believe that people would engage in actual suicidal behaviors for these specific reasons (i.e., $20, avoiding a speech). Rather, these manipulations were designed to be stand-ins for the idea that, in a general sense, some suicides may be caused by the perception that suicide will allow for the attainment of a reward (e.g., family/friends will be better off; reaching a new plane of existence, as in some cult suicides) or the avoidance of a punishment (e.g., facing the consequences of a having committed a crime or losing a job; prolonged physical pain). Should this small proof-of-concept study produce encouraging findings, it may serve as a foundation for studies that examine the effects of much more specific and theoretically-relevant manipulations. We hypothesized that both of these manipulations would lead to an increase in VR suicide completion rates compared to those observed under neutral conditions in Study 2.

11. Method

11.1. Participants

Participants were 32 undergraduate university students (24 females, 75.00%; 8 males, 25.00%) recruited from Psychology courses for research participation credit. Participants had an average age of 23.08 (*SD* = 6.58), with 22 self-reporting as White/Caucasian (68.75%), 6 Hispanic/Latino (18.75%), 3 Black/African-American (9.38%), and 1 Asian/Asian-American (3.13%). Half of the participants (n = 16) were randomly assigned to be offered a reward ($20 Amazon electronic gift card) if they choose to engage in VR suicide (i.e., the reward group). The other half of participants (n = 16) were randomly assigned to be told that they would have to give a speech evaluated by a peer if they did *not* choose to engage in VR suicide (i.e., the avoid group).

11.2. Procedure, materials, and data analytic plan

The procedure for Study 3 was the same as for Study 2, with the exception that the instructions for each VR scenario were slightly different. Specifically, participants in the reward group were informed that they would receive a reward for engaging in VR suicide and participants in the avoid group were informed that they would receive a punishment if they did not engage in VR suicide (see Supplementary Methods S1 under Section Study 3 for these specific instructions). For

qualifying participants in these conditions, immediately before the positive mood induction, they were given $20 or $40 (depending on whether they engaged in VR suicide once or twice in the reward condition) or were asked to give one or two one-minute speeches (depending on whether they did *not* engage in VR suicide once or twice in the avoid condition) that were observed by a member of the research team. See Supplementary Methods S1 under Study 3 for more information on these speech tasks.

We used the same orientation, VR suicide, and positive mood induction scenarios used in Study 2. The only change was a variation in instructions to set the reward and avoid conditions (see Supplementary Methods S1). We used the same computers, VR equipment and laboratory space as used in Studies 1 and 2. In this study, we used the same demographics questionnaire, realism and suicide-relevance items, and reasons for not completing suicide scale used in Study 2. For this study, analyses for realism and suicide-relevance and the *Reasons for not completing VR suicide* questionnaire were identical to those of Study 2. VR suicide completion rate analyses were identical to Study 2 except (a) completion rates were tabulated across the reward and avoid conditions and (b) a Pearson chi-square analysis was conducted to compare the completion rates across the reward/avoid conditions and the neutral conditions of Study 2.

12. Results

Realism and suicide-relevance. Ratings were similar to those observed in Study 2 (see Table 1). Notably, suicide-relevance ratings were higher than observed in Study 2, though the modal ratings for both suicide-relevance (4.0; i.e., the highest rating) and realism (3.0; i.e., the next-to-highest rating) were identical to those observed in Study 2. Realism ratings increased significantly from the first to the second VR suicide administration, but suicide-relevance was unchanged (see Table 1). The jumping scenario was once again rated as significantly more realistic than the shooting scenario, but both were rated as similarly suicide-relevant (Table 1).

VR suicide completion rates. Completion rates were significantly higher than those observed under neutral conditions in Study 2, X^2 (2) = 11.51, *p* = .003. Rates were nearly identical across the first and second administrations, the jumping and shooting scenarios, and the reward and avoid manipulations (see Table 2). Approximately 20% of participants engaged in VR suicide on both of their opportunities.

Reasons for not completing VR suicide. Results were almost identical to those observed in Study 2. Once again, the most strongly endorsed item for not engaging in VR suicide was *Because I'm just not the kind of person who would ever choose the virtual suicide option* (*M* = 3.50, *SD* = 0.72, *Mode* = 4.00), followed by the *Because the virtual suicide option was just too scary* item (*M* = 2.61, *SD* = 1.36, *Mode* = 4.00) and the *Because of moral/religious reasons* item (*M* = 1.45, *SD* = 1.27, *Mode* = 0.00). Likewise, in response to the item *Are there any circumstances under which you would choose the virtual suicide option?*, participants once again indicated that there were few such circumstances (*M* = 0.73, *SD* = 1.17, *Mode* = 0.00).

13. Study 3 discussion

The results of Study 3 were consistent with the possibility that the present approach to VR suicide may allow for tests of causal hypotheses. The reward and avoid manipulations substantially increased VR suicide completion rates (i.e., 25% of opportunities) compared to those observed under neutral conditions in Study 2 (i.e., 5.31% of opportunities). These findings suggest that relatively sudden and simple manipulations can cause large changes in VR suicide completion rates. Study 3 results additionally replicated Study 2 findings that both VR suicide scenarios are generally rated as realistic and suicide-relevant, and that the reasons for *not* engaging in VR suicide are similar to those for *not* engaging in actual suicide.

13.1. General discussion

The nature of suicide makes it difficult to conduct experiments to test ideas about the causes of this deadly phenomenon. This has made it hard to reach consensus about the causes of suicide and to identify targets for interventions. Translational approaches have recently spread to suicide research (e.g., Anestis & Capron, 2016; Gould et al., 2017) in part because they have unique potential to advance knowledge about suicide causes. Taking advantage of new VR technologies, we aimed to take the initial steps toward developing a new laboratory approximation of suicide that could be used within a translational approach. As with all laboratory approximations, the VR suicide approach will always be limited in terms of its ecological validity and ability to cover all facets of suicide (e.g., death). But the tentative causal information produced by VR suicide studies may eventually prove valuable in later studies that seek to predict and prevent actual suicide. Results across the three present studies were supportive of VR suicide as a laboratory approximation of suicide, with five general findings standing out.

First, the VR suicide approach is feasible in terms of both safety and logistics. Regarding safety, there were no indications of nausea, distress, or suicide risk in any study (total N = 498). Moreover, Study 1 experimentally demonstrated that exposure to suicide VR scenarios (vs. control VR scenarios) does not cause any short-term changes in suicide ideation, suicide desire, suicidal capability, implicit associations with death/suicide, implicit affect toward death/suicide, or suicide risk as determined by a clinician. These findings are supportive of the safety of VR suicide scenarios, but future studies would benefit from examining longer-term effects of exposure to these scenarios to further ensure safety. Concerning logistics, this approach is relatively inexpensive, easy to execute and modify, and lends itself to use and replicability.

Second, participants regarded the VR suicide scenarios as unpleasant, realistic, and suicide-relevant. Third, similar to actual suicide, participants who chose *not* to engage in VR suicide reported that they found the prospect of VR suicide to be too scary and noted that they could not imagine any circumstances under which they would ever engage in VR suicide. Fourth, the predictors of VR suicide resembled those of actual suicide, including male sex, suicidal capability, agitation, risk taking, thwarted belongingness, and prior suicidality, among others. Fifth, VR suicide completion rates for the choice-based approach were low under neutral conditions (5.31%) and substantially higher after incentive and disincentive manipulations (25%). This indicates that this approach is amenable to experimental manipulation.

Although findings at this stage are encouraging, it should be kept in mind that the present series of studies represent only the initial development of this approach. Much future work is needed to address the limitations of these studies and to expand beyond the scope of this initial stage of development. The primary limitation that we once again emphasize is that VR suicide is not, and never will be, the same as actual suicide. Individuals in these studies did not engage in actual suicidal behaviors or have actual suicidal intent during these scenarios (to our knowledge). Rather, VR suicide appears to be a meaningful-but-imperfect approximation of actual suicide. It approximates (but does not replicate) the visual, auditory, vestibular, and proprioceptive sensations of suicidal situations and behaviors; it approximates the typical conceptualization of a suicidal situation (i.e., suicide-related); it approximates the reasons that people give for *not* engaging in actual suicide; it approximates the rate of suicide; and it approximates some of the predictors of actual suicide. These approximations (vs. replications) are what make any generalizations from VR suicide to actual suicide *tentative* rather than *definitive*. As described above, such approximations are limiting, but they can provide a firm knowledge base that future studies can attempt to translate into knowledge about actual suicide.

In addition to this general limitation, several more specific limitations and opportunities for improvement should be kept in mind. First, the present series of studies necessarily examined a circumscribed set of ratings about the scenarios (e.g., realism, suicide-relevance) and assessed these ratings after cessation of each scenario. Future studies may benefit from assessing *in vivo* ratings and a wider range of measures (e.g., psychophysiological correlates; immersion and presence). Similarly, the present series of studies necessarily examined a circumscribed set of potential predictors of VR suicide completion. It would be helpful for future work to examine other potential predictors (e.g., various forms of psychopathology). Second, the present series of studies included a convenience sample of undergraduates at a large public university. Future work would benefit from testing the VR suicide approach in much larger samples, clinical samples, and samples of individuals selected for a history of suicidality. Based on the present results, we would expect clinical and suicidal groups to exhibit higher VR suicide completion rates than the present nonclinical samples. Third, it may be helpful to examine the degree to which VR suicide predicts actual suicidal behaviors. Consistent with the small predictive magnitude of actual suicidal behaviors (Ribeiro et al., 2016), we hypothesize that VR suicide would be associated with small predictive effects. Indeed, similar to actual suicidal behaviors, prior suicide plans and attempts were small magnitude predictors of future VR suicide.

Fourth, future work should expand on the present VR scenarios to encompass other aspects of the suicidal process. Specifically, as a starting point, the present VR scenarios drop participants into a situation where they are faced with a forced choice between a suicidal and non-suicidal behavior. This is an efficient and effective approach, but it would be improved by considering aspects such as what might motivate individuals to approach a virtual suicidal situation. Likewise, future work would benefit from developing effective scenarios with fewer instructions, which would improve immersion and presence, adding to ecological validity. Fifth and similarly, new VR scenarios are needed to encompass other suicidal behaviors such as overdoses, self-cutting, drowning, self-immolation, and suffocation. It is notable that the present jumping and shooting scenarios produced very similar results, but a much wider range of VR suicide scenarios would be helpful. We hypothesize that VR suicide rates would be much higher for less obviously lethal virtual behaviors (e.g., virtual overdose). Sixth, future work should continuously integrate technological advancements to further the realism of VR suicide scenarios. For example, new headsets released this year provide an 80% improvement in visual resolution over the prior generation of headsets. Within the next few years, whole-body haptic devices (i.e., devices that mimic the tactile sensations of the virtual environment in real time) will be released commercially, permitting greater immersion and moderate pain stimulation that tracks with what would be expected from the virtual environment.

Seventh, future studies should expand beyond the manipulations employed in Study 3. In particular, future manipulations should mimic putative causes of suicide such as sleep deprivation, experience with prior (virtual) suicidal behaviors, social contagion, and many others. For example, correlational and longitudinal data suggest that social rejection is associated with suicidal behaviors, but cannot speak to social rejection as a potential cause of suicidal behaviors – it may simply be correlated with causes of suicide. To test this possibility, an experiment might randomly assign participants to receive either a social rejection manipulation or a control manipulation, and then have all participants undergo a VR suicide scenario. We would hypothesize that participants in the social rejection condition would be more likely than participants in the control condition to engage in VR suicide. If this were true, then it would represent tentative evidence that social rejection plays a causal role in suicidal behaviors.

In summary, the present series of studies indicates that the VR suicide approach may hold promise as a way to test ideas about suicide causes. As with all other laboratory approximations of psychological and behavioral phenomena, however, we emphasize that this approach necessarily has limited ecological validity and cannot index all facets of suicide. This caveat notwithstanding, we hope that future work will build on these initial studies to further improve this approach to permit tentative tests of ideas about suicide causes.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brat.2018.12.013.

References

Anestis, M. D., & Capron, D. W. (2016). An investigation of persistence through pain and distress as an amplifier of the relationship between suicidal ideation and suicidal behavior. *Journal of Affective Disorders, 196*, 78–82.

Beck, A. T., Steer, R. A., & Ranieri, W. F. (1988). Scale for suicide ideation: Psychometric properties of a self-report version. *Journal of Clinical Psychology, 44*, 499–505.

Blais, A. R., & Weber, E. U. (2006). A domain-specific risk-taking (DOSPERT) scale for adult populations. *Judgment and Decision Making, 1*, 33–47.

Campbell, D. T., & Stanley, J. C. (1963). *Experimental and quasi-experimental designs for research.* Chicago: IL.

Chu, C., Klein, K. M., Buchman-Schmidt, J. M., Hom, M. A., Hagan, C. R., & Joiner, T. E. (2015). Routinized assessment of suicide risk in clinical practice: An empirically informed updated. *Journal of Clinical Psychology, 71*, 1186–1200.

Fleischmann, A., Lammers, J., Conway, P., & Galinsky, A. D. (2019). Paradoxical effects of power on moral thinking: Why power both increases and decreases deontological and utilitarian moral decisions. *Social Psychological and Personality Science, 10*(1), 110–120.

Fox, K. R., Millner, A. J., Mukerji, C. E., & Nock, M. K. (2018). *Examining the role of sex in self-injurious thoughts and behaviors. Clinical Psychology Review*.

Franklin, J. C., Huang, X., Fox, K. R., & Ribeiro, J. D. (2018). What suicide interventions should target. *Current Opinion in Psychology, 22*, 50–53.

Franklin, J. C., Ribeiro, J. D., Fox, K. R., Bentley, K. H., Kleiman, E. M., Huang, X., et al. (2017). Risk factors for suicidal thoughts and behaviors: A meta-analysis of 50 years of research. *Psychological Bulletin, 143*, 187–232.

Gould, T. D., Georgiou, P., Brenner, L. A., Brundin, L., Can, A., Courtet, P.,., et al. (2017). Animal models to improve our understanding and treatment of suicidal behavior.

Translational Psychiatry, 7 e1092.

Hooley, J. M., Ho, D. T., Slater, J., & Lockshin, A. (2010). Pain perception and nonsuicidal self-injury: A laboratory investigation. *Personality Disorders: Theory, Research, and Treatment, 1*, 170–179.

Kraemer, H. C., Kazdin, A. E., Offord, D. R., Kessler, R. C., Jensen, P. S., & Kupfer, D. J. (1997). Coming to terms with risk. *Archives of General Psychiatry, 54*, 337–343.

Linehan, M. M., Goodstein, J. L., Nielsen, S. L., & Chiles, J. A. (1983). Reasons for staying alive when you are thinking of killing yourself: The Reasons for Living Inventory. *Journal of Consulting and Clinical Psychology, 51*, 276–286.

Nock, M. K. (2012). Future directions for the study of suicide and self-injury. *Journal of Clinical Child and Adolescent Psychology,* 255–259.

Ribeiro, J. D., Bender, T. W., Selby, E. A., Hames, J. L., & Joiner, T. E. (2011). Development and validation of a brief self-report measure of agitation: The Brief Agitation Measure. *Journal of Personality Assessment, 93*, 597–604.

Ribeiro, J. D., Franklin, J. C., Fox, K. R., Bentley, K. H., Kleiman, E. M., Chang, B. P., et al. (2016). Self-injurious thoughts and behaviors as risk factors for future suicide ideation, attempts, and death: A meta-analysis of longitudinal studies. *Psychological Medicine, 46*, 225–236.

Ribeiro, J. D., Witte, T. K., Van Orden, K. A., Selby, E. A., Gordon, K. H., Bender, T. W., et al. (2014). Fearlessness about death: The psychometric properties and construct validity of the revision to the Acquired Capability for Suicide Scale. *Psychological Assessment, 26*, 115–126.

Rice, M. E., & Harris, G. T. (2005). Comparing effect sizes in follow-up studies: ROC area, Cohen's d, and r. *Law and Human Behavior, 29*, 615–620.

Van Orden, K. A., Cukrowicz, K. C., Witte, T. K., & Joiner, T. E. (2012). Thwarted belongingness and perceived burdensomeness: Construct validity and psychometric properties of the Interpersonal Needs Questionnaire. *Psychological Assessment, 24*, 197–215.

Watson, D., & Clark, L. A. (1999). *The PANAS-X: Manual for the positive and negative affect schedule-expanded form*.

Woolf, S. H. (2008). The meaning of translational research and why it matters. *Journal of the American Medical Association, 299*, 211–213.

World Health Organization (2017, June 1). Suicide. http://www.who.int/-mental_health/.