Initial Validation of a Virtual Blood Draw Exposure Paradigm for Fear of Blood and Needles

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Abstract

Fear of blood, injections, and needles commonly prevents or delays individuals' receipt of health care, such as vaccines or blood draws. Innovative methods are needed to overcome these fears and reduce anxiety related to activities of this nature. The present study describes initial testing of an arm illusion paradigm that may prove useful during early phases of graded exposure for people with blood and needle fear. Seventy-four undergraduate students aged 18-29 years were tested. In line with study aims, results indicated that the virtual blood draw paradigm promoted strong perceptions of arm ownership and elicited significant changes in physiological indices (blood pressure, heart rate, electrodermal activity, respiratory rate) in response to key procedure elements (e.g., needle insertion). Further, bivariate correlations indicated that individual differences in self-reported blood and needle fear collected prior to the illusion paradigm were significantly associated with presyncopal symptoms reported following the procedure. In regression analyses, self-reported measures of blood and needle fear explained unique variance in presyncopal symptoms even after controlling for general state anxiety. These findings provide initial support for the virtual blood draw paradigm as a promising tool to help provide graded exposure to medical procedures involving needles and blood draw.

Keywords*:* Fear of blood, fear of needles, arm illusion, virtual blood draw, syncope

1. Introduction

Needles and blood draws are used in a variety of medical procedures. In this context, fear of blood and needles represents an important individual and public health concern as it is a documented deterrent to procedures such as routine blood work [22,38], insulin injections and finger sticks for diabetes management [13,39], dental care [7,25], vaccinations [21,32,38], and blood donation [38]. A severe form of this fear – termed blood-injection-injury phobia – is characterized by an intense fear of blood, injections, medical care, and injury; such fear is recognized as excessive and unreasonable by the individual [1]. Blood-injection-injury phobia affects approximately 4% of people in the U.S. However, up to a quarter of the adult population acknowledges experiencing some fear of needles/blood draws [31,32,38].

A unique concern associated with fear of blood or needle stimuli (in comparison to other phobias) is that an individual endorsing such fear may be at increased risk for syncopal symptoms (e.g., dizziness, lightheadedness) or syncope (i.e., transient loss of consciousness) following exposure to blood or needles [10,26,38]. The pre/syncopal response is not universal but affects approximately 80% of individuals endorsing such phobia [28,35]. While the experience of syncopal symptoms is itself considered medically benign, two risks are of note. First, there is an increased risk for physical injury due to falling. Further, the individual may find the symptoms distressing, thus promoting avoidance of future medical or otherwise important procedures [11,12,29].

Considerable evidence suggests that in-vivo exposure is among the most effective interventions for blood-injection-injury phobia, as well as variety of other feared experiences or stimuli [4,23,24,37]. During in-vivo exposure an individual is asked to come into contact with the feared stimulus, usually progressing from the least to most anxiety-provoking aspect of the stimulus [4]. Despite success of established exposure protocols, major limitations include the need for skilled clinicians, a clinical environment, and significant expenditure of cost and time. Accordingly, there is need for relatively inexpensive, accessible, and innovative approaches to deliver exposure to feared stimuli associated with a variety of needle and blood-related procedures.

Recent research has begun to examine the potential utility of body illusions to facilitate exposure paradigms, which may address limitations of conventional treatments [19,30]. For example, the “rubber arm illusion”, first introduced by Botvinick and Cohen in 1998 [3], pairs

tactile stimuli to one's actual arm with that observed on a rubber arm to induce a sense of "ownership" of the rubber arm. Drawing on recent research regarding optimal arm illusion parameters [3,5,20,34,36], the present study examined an extension of this approach by testing simulated ownership of a human arm depicted in virtual/digital format to facilitate exposure to a simulated blood draw. The blood draw procedure was selected due to its relevance to both blood and needles stimuli as well as syncopal response. As such, we sought to establish a foundation for clinical application that could be adapted across various procedures that utilize blood and needle stimuli. Accordingly, the purpose of this preliminary study was to examine the feasibility of a virtual blood draw to generate a realistic subjective experience. Specifically, we examined (1) whether illusion of ownership was successfully induced, (2) the association between self-report measures relevant to blood and needles and presyncopal reactions in response the virtual blood draw, and (3) physiological responses over the course of exposure to the virtual blood draw protocol.

2. Materials Methods

2.1 Participants

Seventy-four undergraduate students participated in this study. Inclusion criteria included (a) age 18 or older, (b) having not donated blood more than once previously, and (c) no self-reported chronic medical conditions that might contraindicate participation in a potentially stressful exposure paradigm (e.g., cardiovascular disease). Potential participants were screened by phone for study inclusion. Participants were recruited from a Psychology Department research participation pool and received compensation in the form of course credit. All participants completed the entire study. All procedures were approved by the University of North Texas Institutional Review Board.

2.2 Self-Report Measures

2.2.1 State-Trait Anxiety Inventory: State Items (STAI-State; [16]). Participant state anxiety was assessed through administration of STAI state items. The STAI-State contains 20 items in which respondents rate their agreement with statements conveying situational anxiety ("I feel nervous"; "I am tense") on a 4-point Likert scale (1=not at all; 4=very much so). Total

scores are obtained for the subscale by summing the 20 items. Higher scores indicate greater state anxiety. Internal consistency (Cronbach's α) for the current sample was α = 0.91.

2.2.2 Blood Donation Fears Inventory (BDFI; [18]). The BDFI is an 18-item survey that assesses individuals' self-reported fear of blood donation across 4 domains (subscales) – syncopal symptoms (9 items), blood and needles (3 items), social evaluation (4 items), and health screen results (2 items). Each item is rated on a 5-point Likert scale (1=not at all afraid or anxious; 5=extremely afraid or anxious). Subscale scores are totaled and divided by the number of items on each subscale to generate an overall score. Higher scores indicate greater fear in each domain. Internal consistency for the total BDFI score in the current sample was α = 0.92. Internal consistency scores for the subscales were as follows: syncopal symptoms (α = .96), blood and needles (α = .92), social evaluation (α = .78), and health screen results (α = .91).

2.2.3 The Fear of Injections and Blood Draws and Fear of Blood subscales of the Medical Fears Survey – Short Version (MFS-SV; [27]). The Fear of Injections and Blood Draws (4 items) and Fear of Blood (5 items) subscales of the MFS-SV allow respondents to indicate the extent to which they experience fear of medically-related situations such receiving injections and giving blood, respectively. These subscales have been shown to predict vasovagal reactions to blood donation [27]. Each item is rated on a five-point scale (0=no fear at all; 4=terror). For the current sample, internal consistency scores were α = .87 for the Fear of Injections and Blood Draws subscale and α = .85 for the Fear of Blood subscale.

2.2.4 Blood Donation Reactions Inventory (BDRI; [9]). Upon completion of the virtual arm protocol (described below), participants completed the 4-item BDRI. The BDRI assesses subjective physiologic reactions to blood donation associated with vasovagal syncope, including faintness, dizziness, weakness, and lightheadedness. Participants indicate the extent to which they experienced each of these symptoms on a 6-point Likert-type scale (0=not at all; 5=extremely); items are summed to provide a total reactions score. Total BDRI scores have a high level of internal consistency, positively correlate with phlebotomist ratings of vasovagal syncope reactions among blood donors, and predict likelihood of future donations [9]. Internal consistency for the current sample was α = .90.

2.2.5 Manipulation Check. Following the virtual arm protocol, participants were asked two questions to assess the extent to which the virtual arm illusion was experienced as realistic. Specifically, participants were asked to respond to the statements *"I felt the touch of the brush on*

the digital arm" and "*I felt as if the digital arm was my arm*" using a 10-point scale ranging from 0 (do not agree at all) to 9 (agree completely). These questions were adapted from earlier studies examining a standard rubber arm illusion [3,14,17] and were administered to capture the key perceptual components of the virtual arm protocol.

2.3 Physiological Measures

2.3.1 Blood Pressure and Heart Rate. Measures of Systolic Blood Pressure (SBP, in mmHg), Diastolic Blood Pressure (DBP, in mmHg), and heart rate (HR, in beats per minute) were obtained using a Dinamap® V100 Digital Blood Pressure monitor. Appropriately-sized blood pressure cuffs were secured to participants' upper left arm and inflated at key phases of the protocol.

2.3.2 Electrodermal Activity. Continuous monitoring of Electrodermal Activity (EDA, in micromhos) was collected using a BIOPAC® MP150 data acquisition system connected to an EDA100C amplifier with two LEAD100 electrodes taped to the middle phalanges of the participants' middle and index fingers. AcqKnowledge®, Version 4 software was used to process the EDA signal and calculate mean levels (in micromhos/minute).

2.3.3 Respiration. Continuous monitoring of respiration rate was collected using a BIOPAC® MP150 data acquisition system connected to an RSP100C respiration amplifier with a TSD201 respiratory effort transducer positioned around the participants' upper chest. AcqKnowledge®, Version 4 software was used to process the respiratory signal and calculate respiration rate (in breaths/minute).

2.4 Procedure

Upon arrival to the laboratory, participants provided consent and completed surveys of demographic information, as well as the STAI-State, BDFI, and MFS-SV Fear of Injections and Blood Draws and Fear of Blood subscales. Participants were then seated, asked to remove any hand jewelry, and asked to position their right arm behind a video monitor (see Figure 1). The video monitor was positioned on a rolling desk and obstructed participants' view of their actual arm. Participants were then fitted with physiological equipment. The following instructions were then provided: *"You will be watching a video of blood being drawn from an arm displayed on the screen. We will be attempting to create the illusion that this arm is your own arm. While you*

will feel sensations similar to those being shown on the video, at no point will a needle be used on your arm, and at no point will blood actually be drawn". Next, participants were instructed to remain seated and refrain from speaking during a 5-minute resting baseline assessment of physiological measures. Following the baseline period, the experimenter initiated the virtual arm illusion.

2.4.1 Induction of Virtual Arm Illusion and Blood Draw. All footage of human arms and blood draws used in this study was previously obtained with consent from six volunteers. Footage of three male and three female arms was collected; each arm in each gender category represented a gradation in skin tone. To maximize the realism of the arm illusion, participants were matched to videos based on gender and skin tone. Each video displayed the arm resting, palm up, against a neutral white surface. Footage of the arm began at approximately five inches proximal of the antecubital fossa (See Figure 2 for still images of virtual arm stimuli).

The illusion of the virtual arm ownership was then induced by integrating visual and tactile stimuli. The virtual (digital) arm appeared in isolation for approximately 2 seconds. Following this, a soft bristle brush was shown repeatedly brushing along the length of the virtual arm (from the elbow to the palmar surface of the hand). In synchrony with the video depiction, the investigator used an identical brush to provide tactile stimuli to the participant's arm positioned behind the monitor (out of sight of the participant; see Figure 1 and Figure 2A). This phase of the protocol lasted approximately 30 seconds and was drawn from prior studies used to generate illusions of rubber arm ownership (e.g., [3]). To maintain consistency between real-world and digital stimuli, the experimenter wore the same white lab coat and gloves as shown in the video.

Next, the video showed a needle and blood flow valve being placed near to the digital arm for 30 seconds (see Figure 2B). The digital arm was then depicted being swabbed with alcohol while the experimenter simultaneously swabbed the participant's arm (10 seconds, see Figure 2C). The needle was then inserted into the arm on the video (see Figure 2D) while the experimenter simultaneously pressed a blunted metal instrument (screwdriver) at the same location on the participant's arm. For the following 60 seconds, participants observed blood being drawn from the digital arm (see Figure 2E). Including intervals between actions (e.g., end of alcohol swab and needle insertion), the entire protocol, including the 5-minute baseline assessment, had a combined duration of approximately 7.2 - 7.5 minutes.

Following completion of the virtual arm protocol, participants completed the manipulation check questions and the BDRI.

2.4.2 Phases of the Protocol Corresponding to Physiological Measures. Collection of physiological measures began at the beginning of the 5-minute resting baseline assessment. Key phases of the protocol were subsequently defined as (a) end of 5-minute resting baseline period – 300-seconds after start of physiological data collection, (b) end of needle insertion – at 370-seconds, and (c) end of digital blood draw – at 430-seconds (combined duration varied slightly, see above). EDA and respiration measures were averaged across phases of the protocol while a single reading of BP and HR was initiated at the end of each of these phases.

3. Statistical Approach

All analyses were conducted using SPSS Version 22.0. Means, standard deviations, and counts were calculated for relevant study variables. Male and female participants were compared on all self-report measures. As self-report questionnaire data were positively skewed, bivariate Spearman correlations were conducted on self-report measures. Subsequently, separate hierarchical linear regression analyses were used to examine the unique/incremental contribution of measures indicating fear of blood and needle stimuli (scores on the BDFI and subscales, and MFS-SV subscales) to participants' self-reported presyncopal symptoms (BDRI) over and above general anxiety (STAI-State), entered into the second block of the regression; potentially relevant demographic variables (gender, age, race, BMI) were entered into the first block. All questionnaire data were log transformed prior to analysis. Finally, 3-Time repeated measures analyses of covariance (RM-ANCOVAs) examined potential changes in physiological measures over key phases of the digital arm protocol (end of baseline period, needle insertion, end of observed blood draw). For each physiological measure, relevant self-report measures (i.e., STAI-State, BDFI total and subscales, MFS-SV subscales) were entered as covariates to explore potential interaction effects. Degrees of freedom vary slightly due to missing/unobtained data across study measures. Effect sizes are reported corresponding to Cohen's f^2 (.02 = small; .15 = medium; and .35 = large effect [6]).

4. Results

4.1 Sample Characteristics

Table 1 provides a summary of participant characteristics for relevant demographic and self-report measures, presented for the full sample and separately for men and women. In comparison to male participants, women scored significantly higher on the MFS-SV Fear of Injections and Blood Draws subscale, $F(1,72) = 4.45$, $p = .04$. Women also scored higher on the BDFI fear of health screen results subscale, $F(1,72) = 4.19$, $p = .04$. No other gender differences were observed.

4.2 Manipulation Check

On average, participant responses to manipulation check items reflected successful induction of arm ownership (see Table 1 for means and standard deviations). Examination of responses to manipulation check items revealed that, of 74 participants, 70 endorsed agreement with the statement "I felt the touch of the brush on the digital arm" (i.e., 6 or above on a 0 – 9 scale). Sixty participants endorsed agreement with the statement "I felt as if the digital arm was my arm" (i.e., 6 or above on a 0 – 9 scale). The response rate is concordant with previous research [2,15]. Induction of digital arm ownership was thus determined to be successful.

4.3 Bivariate Correlations

Table 2 shows bivariate Spearman correlations among self-report study variables. Significant positive associations were observed among all psychosocial measures. Likewise, the two manipulation check items were significantly correlated. Of particular interest to the current study, BDFI total and subscales scores collected prior to the virtual blood draw manipulation showed significant positive correlations with BDRI scores following exposure to the virtual blood draw. Similarly, MFS-SV subscale scores were significantly positively correlated with BDRI scores. Further, higher endorsement of digital arm ownership (in response to the manipulation check item, "I felt as if the digital arm was my arm") was also significantly positively associated with BDRI scores.

4.4 Regression Analyses

Table 3 shows the final model for each predictor variable. Of demographic variables entered in step 1 of the model, only BMI made a significant contribution to explaining variance

in BDRI responses ($F\Delta = 3.69$, $p < .01$), with the block accounting for 18% of the variance in BDRI scores. When added to the model in step 2, the general measure of state anxiety (i.e., STAI-State scores) explained an additional 13% of the variance in BDRI responses ($F\Delta = 13.15$, $p = .001$). Finally, seven individual models were examined by completing step 3 using one of seven specific fear-related measures. As can be seen in Table 3, total BDFI and each of its subscales explained significant additional variance in BDRI scores over and above that explained by demographic variables and general state anxiety. This was also the case for MFS-SV-Fear of Injections and Blood Draws and MFS-SV-Fear of Blood scores, which accounted for 6% and 5% of the variance in BDRI responses, respectively.

4.5 Physiological Outcomes

Figure 3a-e shows changes in physiological measures across key phases of the study protocol (see *2.4.2 Phases of the Protocol Corresponding to Physiological Measures*). SBP, DBP, and respiration all showed significant elevation from the end of the baseline period to the end of needle insertion; $F(1,71) = 44.38$, $p < .001$, $f^2 = .62$ (Figure 3a), $F(1,71) = 31.49$, $p < .001$, $f^2 = .44$ (Figure 3b), and $F(1,71) = 20.53$, $p < .001$, $f^2 = .28$ (Figure 3c), respectively. A significant decline in heart rate was observed between the end of the baseline period and end of needle insertion ($F(1,73) = 13.73$, $p < .001$, $f^2 = .19$; Figure 3d). Finally, a significant elevation in EDA was observed between the end of the baseline period and end of needle insertion ($F(1,73) = 106.28$, $p < .001$, $f^2 = 1.46$) as well as between the end of needle insertion and end of digital blood draw ($F(1,73) = 97.72$, $p < .001$, $f^2 = 1.35$; Figure 3e). No significant interactions were observed with self-report measures.

5. Discussion

This study sought to examine the feasibility of a virtual blood draw to provide a realistic blood draw experience. We examined whether virtual arm ownership could be induced using novel methodology, the association between measures relevant to blood draws and report of presyncopal symptoms following the virtual blood draw, as well as physiological responses during the virtual blood draw protocol. As a primary aim of the current study, responses to the manipulation check revealed that the virtual arm illusion was indeed successfully induced in the majority of participants. This finding is in agreement with research that points to the robust

nature of the rubber arm phenomenon [2,15]. However, to our knowledge this study is the first to utilize a virtual platform to generate the rubber arm illusion in order to simulate a blood draw experience.

Significant bivariate associations between scores on the BDFI and MFS-SV subscales and BDRI responses following the protocol suggest that the virtual blood draw paradigm elicited greater presyncopal symptoms among individuals reporting more fear of the blood draw process. This finding provides initial support for the ability of the virtual paradigm to elicit reactions that are often observed during an actual blood draw, particularly among those with high levels of fear. Validity of the virtual blood draw paradigm is further supported by findings that scores on the BDFI, the MFS-SV-Fear of Injections and Blood Draws subscale, and the MFS-SV-Fear of Blood subscale explained unique variance in reported presyncopal symptoms beyond general state anxiety. Similarly, the positive association between perception of digital arm ownership and BDRI responses provides indirect evidence for the utility of this virtual platform; this finding suggests a potential role for enhancing realistic perceptual experience in development of such methodologies and possible moderation by individual difference factors such as immersability, which have been shown to affect interaction with virtual interfaces [e.g., 33] .

The pattern of physiological activity observed over the course of the protocol provides further support for the validity of the virtual blood draw. Specifically, we observed significant elevation across four physiological indices (SBP, DBP, respiration, and EDA) from the end of the baseline monitoring period to the end of the virtual needle insertion. Interestingly, these increases were accompanied by a significant decrease in heart rate from baseline to the end of needle insertion, and a significant inverse correlation between systolic blood pressure and heart rate changes (r = -0.30, $p < .05$). This pattern of results suggests a potential carotid baroreflex-mediated heart rate deceleration in response to initial blood pressure increases. On the whole, this pattern of elevated physiologic activity may reflect participants' increased anxiety in anticipation of the needle insertion. Anxious physiological reactions in response to perceived threat to a rubber arm have previously been observed [8,15] and interpreted to support the realistic nature of the illusion.

Given the association between BDFI and MFS-SV subscales and presyncopal symptoms, it is surprising that no interactions were observed between these self-report measures and physiological indices. However, given the nature of the current study, one plausible explanation

is that it did not attract participants who were highly fearful of needles or blood draws (see Future Directions below). Thus, it is possible that differential physiological responses corresponding to self-report measures would become more apparent in a sample with higher levels of fear.

Although the current results require replication, they support the virtual blood draw paradigm as a promising tool to help address anxiety related to blood- and needle-related procedures. As noted, fear of needles and blood draws is highly disruptive across a number of medical and nonmedical contexts (e.g., blood donation, blood testing, vaccinations, etc. [18,38]). The virtual platform can be adapted to provide a portable, safe, and flexible analog to practice systematic exposure, desensitization to feared stimuli, or coping skills relevant for blood/needle procedures [37]. Given its ability to induce presyncopal symptoms among fearful participants, the paradigm can provide a context to target such symptoms directly using interventions such as applied muscle tension [23]. The virtual protocol could also be used to simulate exposure to blood donation for individuals who have not previously donated blood or experienced a specific medical procedure. Further, any presyncopal reactions identified in the virtual context may then be addressed prior to actual blood draw.

5.1 Limitations and Future Directions.

The goal of the virtual blood draw paradigm is ultimately to promote reduced fear to blood draw stimuli; however, actual fear or avoidance behavior in response to real world stimuli was not assessed in the current study – interventions and contexts of a more realistic nature should be addressed in future research. In line with this, assessment of the feasibility and ultimate clinical utility of this approach will require testing in target populations, in particular, individuals with BII phobia, who may differ in psychological and physiological responses from nonclinical counterparts. In addition, although this initial validation was conducted in healthy participants, many chronic medical conditions require management using needle procedures (e.g., diabetes) and should be targeted by future research. It is also worth noting that the present study tested a very specific form of blood and needle procedure (i.e., having blood drawn from the arm) more suited for certain contexts, such as blood draw for medical testing and blood donation. Given the flexibility of the virtual paradigm, future studies may wish to examine virtual exposure to a broader range of blood- and needle-relevant scenarios.

In general, given the early nature of body-illusion studies in reference to blood draws and fear of blood draw stimuli, additional research is needed to determine which factors (e.g., visual input, perceived arm ownership, haptic perception) are crucial to the proposed approach; for instance, a natural extension of the current study is comparison of the current protocol (which pairs blood draw footage with induction of arm ownership) with observation of blood draw footage only. As this was the first adaptation of the arm illusion paradigm to a blood/needle procedure, future studies may wish to more specifically assess perceptual experiences related to these stimuli (e.g., the experience needle insertion) as well as psychosocial moderators such as social desirability and immersability. Finally, further research is need to determine what types of virtual interfaces (e.g., fully immersive, audiovisual, haptic) are most compatible with blood draw/needle simulations and with promoting associated health-relevant behaviors.

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Table 1. Characteristics of the participant sample.

	Full Sample (n = 74)				Women (n = 51)				Men (n = 23)			
Variable (Units)	n	Range	Mean	SD	n	Range	Mean	(SD)	n	Range	Mean	(SD)
Dominant Hand[†]												
Right	68	-	-	-	47	-	-	-	21	-	-	-
Left	4	-	-	-	2	-	-	-	2	-	-	-
Race												
White	43	-	-	-	30	-	-	-	13	-	-	-
Black	12	-	-	-	9	-	-	-	3	-	-	-
Asian	4	-	-	-	3	-	-	-	1	-	-	-
Other	15	-	-	-	9	-	-	-	6	-	-	-
Age (years)		18-29	20.2	2.4	-	18-26	10.0	2.0	-	18-29	21.1	3.0
BMI (kg/m^2)	-	19.2 – 41.2	25.3	4.6	-	19.2 – 41.2	25.2	5.0	-	20.2 – 35.0	25.6	3.7
STAI-State	-	20.00 – 61.00	34.1	9.5	-	20.0 – 61.0	35.4	9.7	-	20.0 – 51.0	31.5	8.3
BDFI	-								-			
Total	-	0 – 13.8	5.3	3.8	-	0 – 13.8	5.8	4.1	-	0 – 9.9	4.3	2.7
Syncopal	-	0 – 36.0	11.4	8.7	-	0 – 36.0	12.2	9.0	-	0 – 26.0	9.6	8.0
Blood-Needles	-	0 – 12.0	3.6	3.1	-	0 – 12.0	3.8	3.9	-	0 – 8.0	3.1	2.6
Social Eval.	-	0– 15.0	5.7	3.8	-	0 – 15.0	6.0	4.2	-	0 – 11.0	4.5	2.9
Health Screen[*]	-	0 – 8.0	2.8	2.6	-	0 – 8.0	3.3	3.3	-	0 – 5.0	1.9	1.7
MFS-SV									-			
Injections[*]	-	0 – 13.0	3.6	3.2	-	0 – 13.0	4.1	3.5	-	0 – 8.00	2.8	2.1
Blood	-	0 – 14.0	1.5	2.6	-	0 – 14.0	1.6	2.8	-	0 – 8.0	1.4	2.1
BDRI	-	0 – 13.0	1.9	3.0	-	0 – 13.0	1.8	2.8	-	0 – 13.0	2.0	3.4
Manip. Check												
Felt brush	-	0 – 9	8.0	2.3	-	0 – 9	8.4	2.0	-	0 – 9	7.9	2.0
Felt my arm	-	1 – 9	7.2	2.0	-	2 – 9	7.4	1.7	-	1 – 9	7.3	2.1

[*]*$p < .05$* denotes difference between genders; [†]Denotes sample size varies due to missing/unobtained data; *BMI = Body Mass Index; BDFI = Blood Donation Fears Inventory; BDFI Syncopal = fear of syncopal symptoms; STAI-State = State-Trait Anxiety Inventory – State items; BDFI Blood-Needles = fear of blood and needles; BDFI Social Eval. = fear of social evaluation; BDFI Health Screen = fear of health screen results; MFS-SV = Medical Fears Survey-Short Version; MFS-SV Injections = Fear of Injections and Blood Draws; MFS-SV Blood = Fear of Blood; BDRI = Blood Donation Reactions Inventory; Manip. Check = Manipulation Check: Felt brush = response to "I felt the touch of the brush on the digital arm"; Manipulation Check: Felt my arm = response to "I felt as if the digital arm was my arm".*

Table 2. Spearman correlation among study variables.

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. Age (years)												
2. BMI	.19											
3. STAI-State	-.19	-.15										
4. BDFI Total	-.06	-.41**	.29*									
5. BDFI Syncopal	-.07	-.37**	.26*	.90**								
6. BDFI Blood-Needles	-.16	-.42**	.23*	.85**	.83**							
7. BDFI Social Eval.	-.10	-.30**	.24*	.84**	.67**	.63**						
8. BDFI Health Screen	.10	-.28*	.31**	.84**	.63**	.55**	.73**					
9. MFS-SV Injection	.15	-.36**	.23*	.74**	.56**	.50**	.60**	.82**				
10. MFS-SV Blood	.06	-.33**	.18	.56**	.54**	.50**	.41**	.44**	.48**			
11. BDRI	.06	-.38**	.35**	.61**	.60**	.52**	.45**	.54**	.44**	.37**		
12. Manip - Felt brush	-.23	-.31**	.16	.10	.06	.14	.10	.13	.09	-.06	.13	
13. Manip - Felt my arm	-.18	-.12	.18	.24*	.23*	.26*	.21	.20	.25*	.11	.31**	.51**

**p < .05, **p < .01; BMI = Body Mass Index; STAI-State = State-Trait Anxiety Inventory – State items; BDFI = Blood Donation Fears Inventory; BDFI Syncopal = fear of syncopal symptoms; BDFI Blood-Needles = fear of blood and needles; BDFI Social Eval. = fear of social evaluation; BDFI Health Screen = fear of health screen results; MFS-SV = Medical Fears Survey-Short Version; MFS-SV Injections = Fear of Injections and Blood Draws; MFS-SV Blood = Fear of Blood; BDRI = Blood Donation Reactions Inventory; Manip - Felt brush = response to manipulation check item "I felt the touch of the brush on the digital arm"; Manip - Felt my arm = response to manipulation check item "I felt as if the digital arm was my arm".*

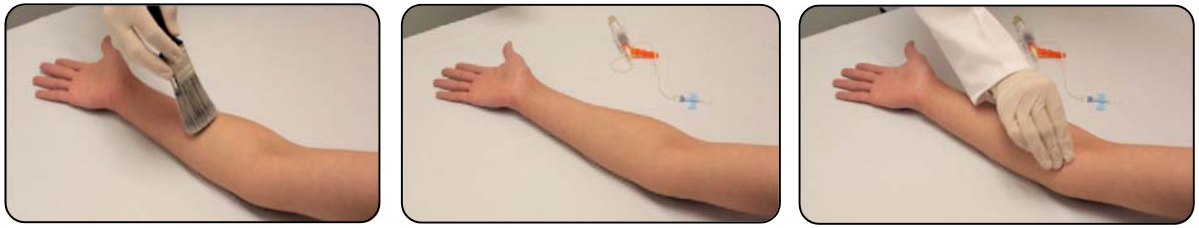
Table 3. Regression analyses for Blood Donation Reactions Inventory scores

	R^2 change	*F*	*β*	*t*	f^2
Step 1	.18	3.70**			21
Age (years)			.12	1.05	
Gender (male = 1)			-.02	-.15	
Body Mass Index (kg/m^2)			-.39	-3.56**	
Race (White = 2; Non-White = 1)			-.11	-.94	
Step 2					
STAI-State	.13	6.11**	.38	3.63**	.15
Step 3[a]					
Model 1. BDFI Total	.14	9.09**	.44	4.11**	.16
Model 2. BDFI Syncopal	.12	8.40**	.39	3.74**	.14
Model 3. BDFI Blood-Needles	.14	9.00**	.42	4.06**	.16
Model 4. BDFI Social Eval	.07	6.89**	.30	2.78**	.08
Model 5. BDFI Health Screen	.11	7.95**	.37	3.49**	.12
Model 6. MFS-SV Injection	.05	6.35**	.27	2.35*	.05
Model 7. MFS-SV Blood	.06	6.44**	.25	2.43*	.06

*$p < .05$, **$p < .01$, *All self-report questionnaire data were log transformed prior to analysis; results did not differ substantially between transformed and non-transformed data.* [a] *For the third step in the regression, results are presented for separate models if the specific fear variable was entered. STAI-State = State Trait Anxiety Inventory – State items; BDFI = Blood Donation Fears Inventory; BDFI Syncopal = fear of syncopal symptoms; BDFI Blood-Needles = fear of blood and needles; BDFI Social Eval. = fear of social evaluation; BDFI Health Screen = fear of health screen results; MFS = Medical Fears Survey-Short Version; MFS - SV Injections = Fear of Injections and Blood Draws; MFS-SV Blood = Fear of Blood*

Figure 1. Participant undergoing virtual arm protocol.

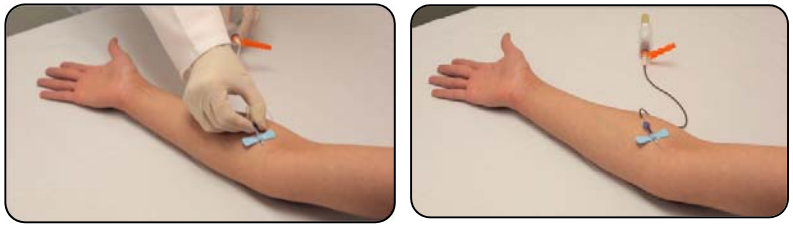
Figure 2. Overview of virtual arm protocol.



A. Induction of digital arm ownership.

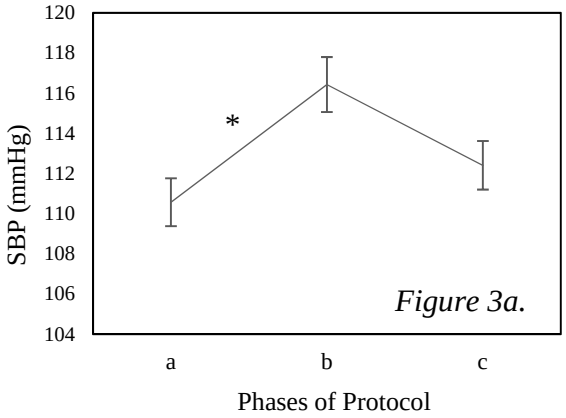
B. Needle stimuli in proximity to arm.

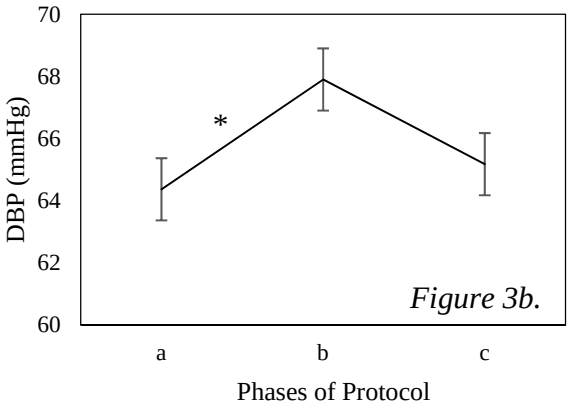
C. Alcohol swab.

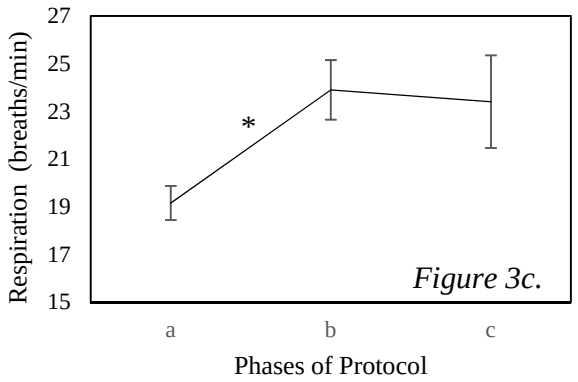


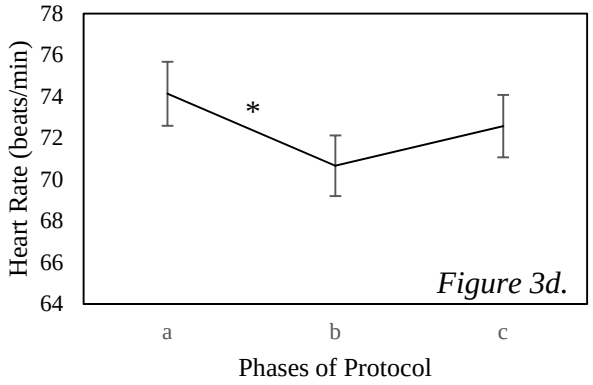
D. Needle insertion.

E. Blood draw.









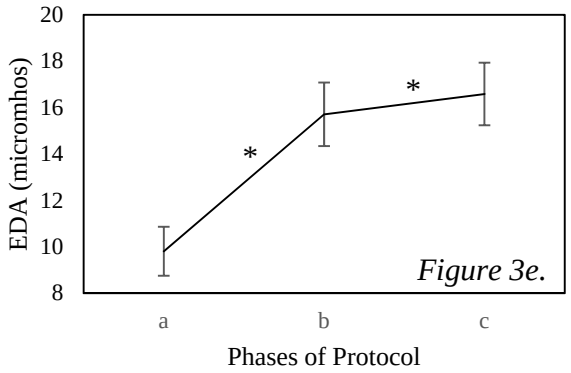


Figure 3a - e. Key phases of the protocol: (a) end of 5-minute resting baseline period (b) end of needle insertion, and (c) end of digital blood draw. *Indicates significant change.