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Mortality Salience in Virtual Reality Experiences and its Effects on Users' Attitudes towards Risk

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Abstract

Virtual reality (VR) is increasingly used as a persuasive technology for attitude and behavior change. This paper considers *Terror Management Theory* (TMT), one of the notable theories that have not been considered so far in persuasive technology, and aims at exploring its use in VR experiences. First, we show that a VR experience can be used to effectively elicit *mortality salience* (MS), which makes TMT applicable. Then, we evaluate the effects of the VR experience on attitudes towards risk. Wearing a *head-mounted display* (HMD), participants explored one of two virtual environments (VEs). In a first group of participants, the VE represented a cemetery with MS cues like tombs and burial recesses. In a second group of participants, the MS cues were removed, and the VE looked like a public park. Results show that the MS cues manipulation changed the effects of the VR experience on users' attitudes towards risk, as TMT would predict. Moreover, results revealed a relationship between MS elicited through VR and physiological correlates of arousal. Finally, we show that user's personality traits can moderate the effects of the VR experience on attitudes towards risk.

Keywords: virtual reality, persuasive technology, Terror Management Theory, attitudes towards risk, mortality salience, physiological arousal, personality traits

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1. Introduction

Virtual reality (VR) is increasingly used as a technology for attitude and behavior change, for diverse purposes that range from treatment of psychological disorders (e.g., Baños et al, 2011; Lister, Piercey, & Joordens, 2010; Rizzo et al., 2010) to health promotion (e.g., Fox & Bailenson, 2009; Fox, Bailenson, & Binney, 2009) and consumer persuasion (e.g., Ahn & Bailenson, 2011).

Researchers in persuasive technology are working at establishing connections between the experiences provided by interactive systems and the theories of persuasion developed in psychology. The purpose of such multidisciplinary effort is twofold: providing better grounding to the design and evaluation of persuasive interactive systems, as well as finding new strategies that such systems can adopt to affect user's attitude and behavior – for an up-to-date listing of the psychological theories considered so far in persuasive technology research, see (Spagnolli, Chittaro, & Gamberini, 2016). *Terror Management Theory* (TMT; Greenberg, Pyszczynski, & Solomon, 1986) is one of the notable theories that have not been considered so far in this context, although the psychology literature has clearly highlighted its importance for attitude and behavior change, especially in the health (e.g., Vail et al., 2012; McCabe, Vail, Arndt, & Goldenberg, 2014) and consumer persuasion (e.g., Maheswaran & Agrawal, 2004) domains. The TMT approach to attitude change is based on eliciting *mortality salience* (MS), i.e., an individual's awareness of his/her own mortality, by stimulating people with reminders of mortality (*MS cues*). If the elicitation is effective, the theory predicts effects such as more motivation to enhance physical health (Vail et al., 2012) or adopt safer behaviors (Shehryar & Hunt, 2005).

This paper aims at exploring the possibility of using TMT in virtual reality (VR) experiences. Since TMT studies in the literature use non-VR instruments to elicit MS, our first research goal concerns determining if VR can be effectively used to elicit MS. If MS is effectively elicited by a VR experience, our second goal is to evaluate the possible effects of the VR experience on user's attitudes, focusing on attitudes towards risk. Furthermore, since VR can elicit user's physiological responses that are consistent with real-world experiences (e.g., Parsons et al., 2009), our third goal is to evaluate the effects of the proposed VR-based MS manipulation on participants' physiological activity. Finally, since individual differences in personality play a role in determining the effects of VR experiences (e.g., Kober & Neuper, 2013) as well as of MS (e.g., Goldenberg et al., 2006; Niemiec et al., 2010), our fourth goal is to analyze how such role could manifest itself in the context of VR experiences that aim at eliciting MS.

The paper is organized as follows. First, we review the related work on TMT, VR and attitude change, and the impact of individual personality differences on VR experiences and MS effects. Then, we describe in detail the study we carried out to pursue the above mentioned four goals. Finally, we critically discuss the results of the study, and present conclusions and future work.

2. Related Work

2.1. Terror Management Theory

MS can affect attitudes and behaviors (e.g., Magee & Kalyanaraman, 2009; Maheswaran & Agrawal, 2004), and TMT provides a viable framework to examine such effects (Maheswaran & Agrawal, 2004). According to TMT, the most basic of all human motivations is the preservation of the self and the instinctive desire for continued life (Miller & Mulligan, 2002), and MS can thus generate death anxiety in the individual. Pyszczynski, Greenberg, and Solomon (1999) propose a *dual-process model* of TMT that describes how people respond to such anxiety. If mortality awareness is conscious, i.e., the death-related thoughts are in focal attention, pseudo-rational efforts to cope with one's vulnerability to mortality are triggered to push these thoughts out of focal attention (*proximal defense* processes, see Pyszczynski et al., 1999). Usually, such efforts are related to seeking distractions, e.g., turning up the radio after passing a gruesome accident scene on the road. Death-related thoughts become then non-conscious, but remain highly accessible: at this stage, more symbolic and culturally-oriented responses are triggered (*distal defense* processes, see Pyszczynski et al., 1999), which are related to the defense of one's own cultural worldview, i.e., his/her cultural conception of reality, and to the potentiation of his/her self-esteem, in terms of being a valued member within his/her worldview (Arndt, Greenberg, Pyszczynski, & Solomon, 1997; Burke, Martens, & Faucher, 2010; Du et al., 2013; Harmon-Jones et al., 1997; Rosenblatt, Greenberg, Solomon, Pyszczynski, & Lyon, 1989). For example, MS influences an individual into rating people of the same religion or nationality more favorably with respect to people of a different religion or nationality (Castano, Yzerbyt, & Paladino, 2004; Greenberg et al., 1990).

Proximal and distal defense responses to MS can influence how an individual processes a persuasive message (Hansen, Winzeler, Topolinski, 2010; Magee & Kalyanaraman, 2009). For example, TMT helped researchers in the health domain to explain why conscious death-related thoughts can be able to motivate people to enhance their physical health and prioritize growth-oriented goals (Vail et al., 2012): the achievement of these goals may be perceived by individuals as a coping option that helps pushing death thoughts out of conscious awareness. TMT can also be a valuable instrument to understand additional, complex phenomena that occur in the persuasive communication domain. For example, McCabe et al. (2014) compared the effectiveness of endorsement for health behavior decisions (responsible alcohol consumption) when the endorser is health-oriented (doctor) or culture-oriented (celebrity). The authors observed that the presence of death thoughts in focal attention increased the effectiveness of health-oriented endorsers, but not culture-oriented endorsers, while the presence of death thoughts outside of focal attention increased the effectiveness of culture-oriented endorsers, but not health-oriented endorsers. Furthermore, in the case of death thoughts outside of focal attention, the effectiveness of health-related messages promoted by a celebrity was effective only if the celebrity was perceived as popular and successful, i.e., if the celebrity is characterized as possessing cultural value for participants.

TMT can also be exploited in the context of consumer behavior: as discussed in (McCabe et al., 2014), conscious and unconscious death thoughts can have a different impact on the effectiveness of commercial endorsement for a consumer product (even a simple one like bottled water), in the same way as we summarized previously for the case of health-related persuasive communications. Moreover, the defense of one's own cultural worldview may explain consumers' stronger preference, in response to MS, for products from their preferred brand (i.e., products that might help to support their existing worldview) instead of ones from competing brands (Maheswaran & Agrawal, 2004).

Finally, TMT has helped researchers to explain the effects of MS on attitudes towards risk, with findings consistent with those on health motivation. In particular, distal defense processes are related to changes in attitudes towards risk (e.g., Ben-Ari, Florian, & Mikulincer, 1999), and MS elicitation can be used to increase risk perception and decrease risk taking (Miller & Mulligan, 2002). However, such MS effects seem to be mediated by personality differences in the individual's orientation of *locus of control* (LoC), i.e., the extent to which an individual perceives that an event is contingent upon his/her own behavior (*internal* orientation of LoC), or is the result of luck, chance, fate, as under the control of powerful others or as unpredictable because of the great complexity of the forces surrounding him/her (*external* orientation of LoC) (Rotter, 1966). Miller and Mulligan (2002) observed that MS increases the perception of risk for the self in both internally and externally-oriented individuals, while the perception of risk for others increases in internally-oriented individuals, and decreases in externally-oriented individuals. These results suggest that, to evaluate appropriately the effects of MS on risk perception, a study has to control for individual differences in LoC.

2.1.1. VR for attitude and behavior change.

Immersive VR experiences are increasingly employed for persuasion in different domains, such as: health, e.g., attitude towards physical exercise (Fox & Bailenson, 2009; Kim, Prestopnik, & Biocca, 2014; IJsselsteijn, de Kort, Westerink, de Jager, & Bonants, 2006) and perception of risk related to unhealthy food (Ahn, Fox, & Hahm, 2014); safety, e.g., perception of fire risks (Chittaro & Zangrando, 2010); social skills, e.g., engagement in prosocial behaviors (Rosenberg, Baughman, & Bailenson, 2013); environmental sustainability, e.g., attitude towards paper conservation (Ahn, Fox, Dale, & Avant, 2015) and climate change (Zaalberg & Midden, 2010); advertising, e.g., brand attitude and purchase intention (Ahn & Bailenson, 2011; Hanus & Fox, 2015).

Multimodal sensory stimulation and immersion provided by VR experiences can play a fundamental role in improving the impact of a persuasive message compared to more traditional materials such as pictures or videos. For example, Zaalberg and Midden (2010) observed that a 3D simulation of a flooding experience increased users' motivation towards safety behaviors more than 2D pictures. The use of virtual characters in the VE has also been studied, especially in the health domain, for effectiveness in promoting behavior change (e.g., Fox & Bailenson, 2009; IJsselsteijn et al., 2006). For example, virtual representations of the user seem to increase the effectiveness of the persuasive message more than virtual representations of other people (Ahn & Bailenson, 2011; Ahn et al., 2014; Fox & Bailenson, 2009). Interactivity is a feature of VR experiences that can make them more effective than traditional materials: Ahn et al. (2014) observed that two interactive VR experiences (requiring users to cut down a tree or nurturing a seedling into a mature tree) led to a greater behavior change towards environmental sustainability compared to non-interactive versions of the same experiences. Showing the links between cause and effect for persuasive purposes (Fogg, 2003) is a technique that is often exploited in current VR experiences. For example, the persuasive application proposed in (Fox & Bailenson, 2009), which displays a virtual representation of the user gaining or losing weight in accordance with his/her physical exercise behavior, was more persuasive compared to other versions of the application that did not provide such feedback. The emotional intensity of the virtual experience plays a role too, as discussed in (Chittaro & Zangrando, 2010; Chittaro & Buttussi, 2015).

The effectiveness of VR for attitude and behavior change has also been exploited for the treatment of anxiety disorders. More specifically, the literature has studied virtual reality exposure therapy (VRET) as an efficient and less costly alternative to in-vivo exposure for the treatment of phobias (e.g., aviophobia, i.e., fear of flying) and other anxiety-related disorders (Baños et al, 2011;

Lister, Piercey, & Joordens, 2010; Meyerbröker, & Emmelkamp, 2010; Parsons & Rizzo, 2008; Rizzo et al., 2010; Wiederhold & Wiederhold, 2000).

2.1.2. MS elicitation and VR.

The TMT literature employs a wide array of instruments to elicit MS in people, many of which are unfortunately not conceived for practical inclusion in interactive applications for attitude change, and could disrupt users’ engagement with the application itself. As described in the meta-analysis by Burke et al. (2010), most studies employ the Mortality Attitudes Personality Survey, first described in (Rosenblatt et al., 1989). In this instrument, two open-ended questions ask participants to write about what will happen as they physically die, as well as about the emotions elicited by thinking about their own death. Questionnaires and scales that contain death-related questions, such as the Fear of Death questionnaire, are also employed to elicit MS (e.g., Zaleskiewicz, Gasiorowska, & Kesebir, 2015). Other studies resort instead to subliminal reminders of death (implicit MS cues), e.g., by presenting death-related words at the center of a computer screen for a few milliseconds between two mask-words unrelated to death, during a computer-based task that requires participants to decide as quickly as possible whether the two words are related or unrelated (Arndt et al., 1997; Landau et al., 2004). Additional instruments for MS manipulation reported by Burke et al. (2010) involve being: i) interviewed in front of a cemetery; ii) shown videos of graves in a cemetery; iii) presented with scenes from the Holocaust; and iv) shown pictures containing elements and words related to death. Burke et al. (2010) observed that these instruments seem to be equally capable to elicit MS, and that their effects are similar in magnitude. However, their survey could not include VR, because VR and videogame technology has been used a few times in TMT studies only as a measurement tool, to assess the effects of prior MS manipulations that were conducted with the traditional elicitation instruments summarized above. For example, Ben-Ari et al. (1999) measured the impact of a prior MS manipulation on participants’ behavior, in the form of average driving speed in an arcade car simulator. To the best of our knowledge, no TMT studies have employed VR to elicit MS.

As anticipated in the Introduction, the first goal of our study is to assess if VR can be employed to successfully manipulate MS. If VR were effective for eliciting MS, not only it would be useful to build interactive applications for attitude change, but it would also contribute to tackle some issues that are typical of TMT studies. An important issue is the tradeoff between the need for full control over the experiment and the degree to which experimental conditions are similar to situations encountered in everyday life, a common issue in social psychology as discussed by (Blascovich et al. (2002). VR can be more ecologically valid than traditional, non-interactive stimuli such as written text and audio-visual materials (Parsons, 2011). At the same time, VR allows for near-perfect control over the experimental environment and actions within it (Blascovich et al., 2002; Kinateder et al., 2014). Furthermore, mundane realism can increase participants' engagement with experimental situations, and their sensitivity to independent variable manipulations, possibly increasing experimental impact (Blascovich et al., 2002).

2.1.3. Physiological responses to MS.

Only a few studies in the TMT literature included physiological variables in the assessment of MS effects. Some results were obtained by Martens et al. (2008, 2010) who focused on the relationship between physiology and self-esteem in a MS condition only. They found a positive relationship between cardiac vagal tone (which is negatively correlated to arousal, see Andreassi, 2007) and self-esteem, claiming that both operate as a coping response to MS and threats. Similarly, Greenberg et al. (1992) focused on the relationship between self-esteem and anxiety: they measured participants' *electrodermal activity* (EDA), a physiological correlate of arousal (Andreassi, 2007), and found that the anxiety-buffering effects of self-esteem extend to an individual's physiology. However, when conditions in which MS was elicited were compared with conditions in which it is not, there was no clear evidence that MS manipulation caused higher levels of negative affect, physiological arousal, or other forms of psychological distress (Pyszczynski et al., 1999). For example, Rosenblatt et al. (1989) measured EDA together with other correlates of arousal, i.e., blood volume pulse amplitude and *heart rate* (HR) (Andreassi, 2007), but could not find differences among participants who responded to a MS-inducing questionnaire, participants who responded to questions about eating, and participants who did not respond to any questions. Similarly, Arndt, Greenberg, and Allen (2001) did not observe differences in EDA and HR between participants who completed an MS-inducing questionnaire and participants who completed an exam salience questionnaire.

One must also consider that these studies only considered explicit MS cues, i.e., cues that push mortality awareness into conscious attention like the Mortality Attitudes Personality Survey. Other studies suggest that affective responses can be produced by implicit MS cues: for example, *corrugator* muscle activity (which is correlated to negative affect, see Andreassi, 2007) was greater during exposure to subliminal MS cues with respect to subliminal stimuli related to pain (Arndt, Allen, & Greenberg, 2001). Neuroimaging studies suggest that arousal should also emerge in case of explicit MS cues. It has indeed been observed that individuals' processing of death-related and negatively-valenced words is characterized by activation of brain regions (*precuneus/posterior cingulate* and *lateral prefrontal cortex*) associated with arousal and emotion regulation, suggesting that such neurocognitive processes may provide a mechanism that moderates death anxiety (Han, Qin, & Ma, 2010). Also, explicit MS cues seem to produce activation of the *right amygdala* (Quirin et al., 2012), a brain structure of the limbic system involved in processing a class of emotions characterized by negative valence and high arousal (Adolphs, Russell, & Tranel, 1999). This brain structure has also been associated to fear and alertness (LeDoux, 1998). Despite the current lack of results about physiological responses to explicit MS cues, results reported in the mentioned studies encourage to assess in more depth the relationship between explicit MS cues and physiological responses.

2.2. Individual Differences

Individual differences in personality play a role in determining user's responses to and subjective experience of VR (e.g., Kober & Neuper, 2013; Murray, Fox, & Pettifer, 2007; Wallach, Safir, & Samana, 2010; Wiederhold & Wiederhold, 2000). They also play a role in moderating the effects of MS (e.g., Goldenberg et al., 2006; Joireman & Duell, 2007; Niemiec et al., 2010).

The VR literature that considered user's personality focused mostly on how personality can influence sense of presence. Kober and Neuper (2013) explored different personality variables, observing that absorption (a personality variable indicating the extent to which someone becomes fully involved or immersed in events or objects) seems to be the best predictor for the feeling of presence in VR. Presence is also related to LoC: users with an external LoC orientation are more likely to experience a strong sense of presence in VR than individuals characterized by an internal orientation (Murray et al., 2007; Wallach et al., 2010). As previously reported, LoC seems also to play a role in moderating the effects of MS on attitudes towards risk: Miller & Mulligan (2002) showed how individuals with an internal LoC exhibit increased risk assessment in response to MS. Furthermore, self-esteem is a personality variable that influences the effects of MS on attitudes and behaviors broadly (Hansen et al., 2010; Shehryar & Hunt, 2005), and is the second most commonly employed moderator in TMT studies (Burke et al., 2010).

In addition to self-esteem and LoC, other personality traits seem to be able to influence individual responses to MS. Niemiec et al. (2010) observed that defensive responses to MS are reduced by *trait mindfulness*, a personality trait that concerns the extent to which the individual attends to the present moment (Siegling & Petrides, 2014). Baer, Smith, Hopkins, Krietemeyer, and Toney (2006) examined the structure of the mindfulness construct, and identified five facets that compose it (Baer et al., 2006; 2008). These five facets are represented in the *Five-Facet Mindfulness Questionnaire* (FFMQ; Baer et al., 2006; 2008), which measures the skills related to the identified facets through the following subscales:

- *Observing*: the ability to notice or attend to internal and external experiences such as sensations, cognitions, emotions, sights, sounds, and smells;
- *Describing*: the ability to label internal experiences with words;
- *Acting with awareness*: the ability to attend to one's own activities of the moment rather than behave mechanically while attention is focused elsewhere;
- *Non-judging of inner experience*: the ability to take a non-evaluative stance towards thoughts and feelings;
- *Non-reactivity to inner experience*: the ability to allow thoughts and feelings to come and go, without getting caught up in or carried away by them.

The mindfulness variable measured by Niemiec et al. (2010) is related to one of FFMQ facets, i.e., acting with awareness. To the best of our knowledge, no study considered the moderating effects of all the five mindfulness facets.

Neuroticism, a personality variable negatively related to trait mindfulness, and characterized by high levels of anxiety, worry, impulsiveness, moodiness and self-criticism (Costa & McCrae, 1992), seems to be a moderator for the impact of MS, e.g., on an individual's attitudes towards their physical body (Goldenberg et al., 2006): highly neurotic individuals tend to avoid physical sensations, even pleasant ones (such as using an electric foot massager), when MS is induced (Goldenberg et al., 2006).

3. Hypotheses

The study we present in this paper explored four hypotheses. First, we hypothesized that VR can be employed to successfully elicit MS. Second, based on the TMT literature (e.g., Miller & Mulligan, 2002), we hypothesized that, if VR can effectively elicit MS, then the virtual experience should affect user's attitudes towards risk, measured as an increased perception of risks related to hazardous behaviors. To correctly evaluate these effects of MS, individuals' self-esteem and LoC must be accounted for, given their moderating effects on attitudes towards risk (see Ben-Ari et al., 1999; Miller & Mulligan, 2002). Third, we hypothesized that MS cues presented by the proposed VR experience should be able to elicit a significant physiological response in users. As reported in the literature, VR can elicit in users physiological responses that are consistent with real-world experiences (Parsons et al., 2009; Slater, Khanna, Mortensen, & Yu, 2009; Meehan, Razzaque, Insko, Whitton, & Brooks, 2005; Chittaro, 2014; Zanon, Novembre, Zangrando, Chittaro, & Silani, 2014; Patil, Cogoni, Zangrando, Chittaro, & Silani, 2014). In the present study, we thus included an evaluation of MS manipulation effects on participants' physiological activity. We focused in particular on circulatory activity variables that are correlated with sympathetic nervous system activation, and have been employed in the literature as indexes of participants' stress and anxiety in virtual experiences (Kim, Rosenthal, Zielinski, & Brady, 2014; Parsons et al., 2009; Sioni & Chittaro, 2015).

The fourth hypothesis concerned the possible role of user's personality traits on how eliciting MS with a VR experience affects users' attitudes towards risk. To the best of our knowledge, no study has yet evaluated the possible relationship among MS, personality traits, and perception of risk. In particular, we focused on assessing the moderating role of two traits: mindfulness (described in the previous section), and *harm avoidance* (HA). HA is a personality trait related to worry and fear that might be a moderator of the effects of MS manipulations, because it is positively correlated with the previously discussed neuroticism (De Fruyt, Van De Wiele, & Van Heeringen, 2000). For this reason, we hypothesized that individuals with high levels of HA should be more affected by the presence or absence of MS cues than individuals with low levels of HA. On the contrary, individuals with high levels of mindfulness exhibit reduced defensive responses to MS cues (Niemiec et al., 2010), so they should be less affected by the manipulation than individuals with low levels of mindfulness. Compared to Niemiec et al. (2010), we evaluated the possible moderating role of a larger number of mindfulness facets (see Section 2.2) in the measured effects of MS on attitude towards risk.

4. Virtual Environments

To test the hypotheses, we created two versions of the same virtual environment (VE). The first version (cemetery VE) reproduced a virtual cemetery, presenting users with environmental MS cues (tombs, burial recesses, and a group of mourners attending a funeral). In the second version (park VE), we replaced the environmental MS cues with items (flowerbeds, wood benches and tables, a group of people having a picnic) designed to make the environment look like a public park instead of a cemetery.

In building the cemetery VE, we followed architectural and aesthetic conventions that are typical of cemeteries in the country of study participants. The environment was surrounded by walls, and divided it into eight areas (Figure 1).

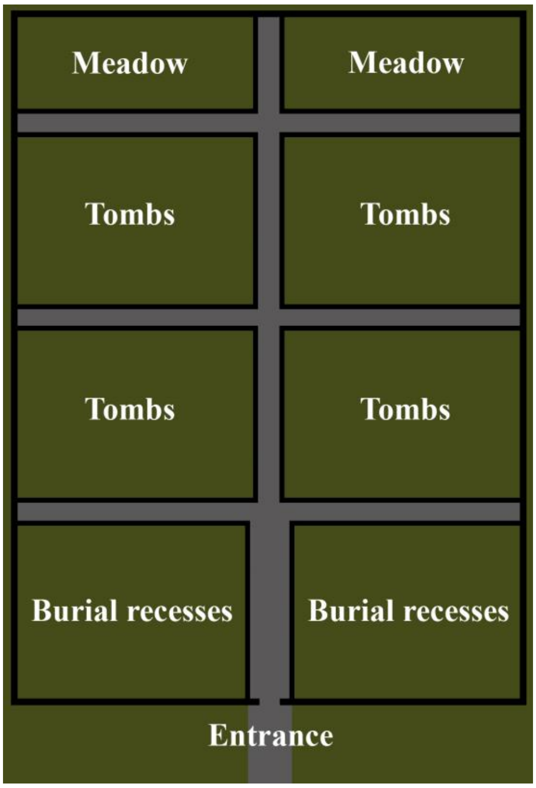

Figure 1. A schematic map of the cemetery.

Each one of the two areas labeled as “Burial recesses” in Figure 1 contained three groups of burial recesses (Figure 2a). The four areas labeled as “Tombs” in Figure 1contained individual as well as family tombs (Figure 2b). Tombs are surrounded by grass and flowers, and paths of concrete tiles allow visitors to reach any tomb. The two areas labeled as “Meadow” in Figure 1, which were the farthest from the cemetery entrance, were meadows without tombs. The VE included cypress trees (Figures 2a and 2b) and oak trees (Figure 2b).

a b

Figure 2. Screenshots of the cemetery VE: (a) burial recesses, (b) individual tombs.

In one of the tombs areas, a funeral was taking place (Figure 3): a group of mourning people (six women, four men, and six children) were gathered around an open grave, near the coffin, while a priest was reading a death-related religious text from the Book of Wisdom (chapter 3, verses 1-9).

Figure 3. On the left, a red circle shows the location of the funeral on the VE map. On the right, a screenshot of the funeral.

Participants could hear the sound of their footsteps inside the VE, as well as sounds of a light wind blowing and crows cawing.

To create the park VE, we removed the MS cues described above from the cemetery VE and replaced them with items typical of public parks in the country of study participants, i.e., wood benches and tables surrounded by flowerbeds (Figure 4a). The group of people gathered for the funeral in the cemetery VE was replaced by a group of people having a picnic, and the reading priest in the cemetery VE was replaced by a man reading an extract from a novel that did not mention death or mortality, and described a character in neutral tones (Figure 4b). The group of people was composed by the same virtual men, women and children of the funeral, but their dark clothes were replaced with more colorful clothes. All other VE elements (walls, trees, roads, concrete tile paths, wind and crow sounds) and the VE map were left unchanged.

a b

Figure 4. Screenshots of the park VE: (a) wood benches and beds of yellow flowers; (b) the group of people having a picnic.

The task assigned to participants was to walk virtually in either the cemetery VE or the park VE for 300 s, following a given path (Figure 5). The path was indicated by a series of blue markers placed on the ground, each one including a white arrow pointing in the direction that participants had to follow to reach the next marker (Figure 6). In any location along the path, participants could see the next three markers of the path. The path had been defined in such a way that it allowed participants to visit most of the VE and to pass near the group of people involved in the funeral (cemetery VE) or the picnic (park VE). The walking speed and the path length made it impossible for participants to go beyond the end of the path within the 300 s limit.

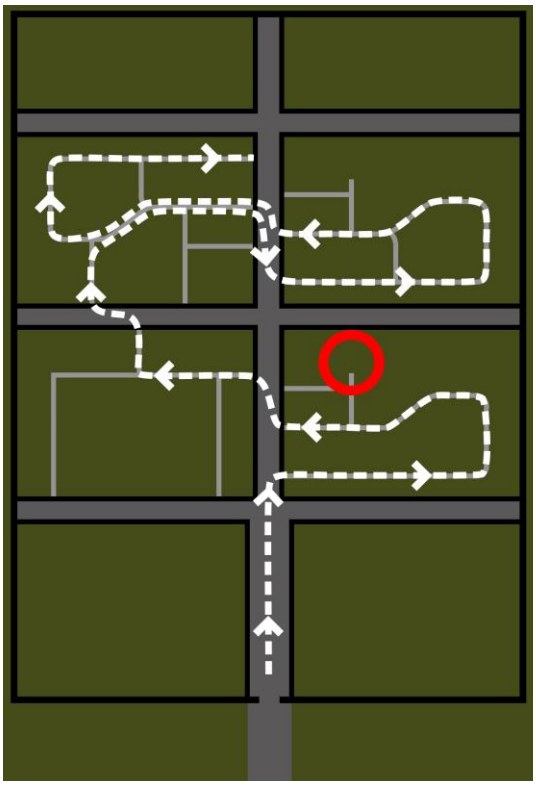

Figure 5. A schematic map of the VE showing the path (white dashed line) that participants had to follow. Arrowheads indicate direction of movement.

Figure 6. A screenshot of the park VE including one of the blue circles that indicated the navigation path.

5. Experimental Evaluation

5.1. Participants

Participants (*n* = 108) were recruited among graduate and undergraduate students at our university, and received course credit for participation. The data collected through three of the questionnaires described in the following (demographic, self-esteem, and LoC questionnaires) were used to evenly assign participants to the two experimental groups. Three participants abandoned the experimental task because of cybersickness (LaViola, 2000) caused by the HMD, and were thus excluded from the study. As a result, we completed the data collection with 105 participants (10 M, 95 F).

5.2. Materials and measures

5.2.1. Computer hardware. To move inside the VEs, participants used a Nintendo Nunchuck controller, equipped with a joystick. By moving the joystick forward or backward, participants walked respectively forward and backward in the VE; by moving the joystick to the left or to the right, participants rotated respectively counter-clockwise and clockwise in the VE.

To display the VEs and reproduce sound, we employed a Sony HMZ-T1 stereoscopic HMD (two OLED displays each with 1280x720 resolution, 45° field-of-view), equipped with built-in headphones. We used a 3-DOF sensor (Intersense InertiaCube3) attached to the HMD to track participant’s head movements, and update the view of the VE accordingly: by rotating their head, participants could change the direction they were looking at independently from their walking direction. The HMD was connected to a PC with a 2.67 GHz Intel Core i7 processor, 6 GB of RAM and two Nvidia GeForce GTX 260 GPUs in SLI configuration.

To record participants’ physiological data, we employed a Thought Technology ProComp Infiniti encoder, and Biograph Infiniti software. Data was recorded at 2048 Hz.

5.2.2. Demographic questionnaire. Participants were asked about their age and sex. As explained in Section 5.1, sex and age were two of the variables that we used to assign participants to the two experimental groups in a balanced way. Sex is the most common moderator variable employed in the TMT literature (Burke et al., 2010).

5.2.3. Temperament and Character Inventory (TCI). The TCI (Cloninger, Svrakic, & Przybeck, 1993) is a comprehensive instrument to measure several differences in personality (Cloninger et al., 1993). In our study, it was used to measure HA. Participants rate TCI items as true or false. The score for each subscale is calculated by adding one point for each item of the subscale answered appropriately: for each item, the TCI provides the experimenter with a reference response (true or false) against which participants' responses are checked (Cloninger et al., 1993). We used 47 of the TCI 240 items: the 35 items that constitute the HA subscale, and 12 filler items. HA score is in the 0-35 range. Cronbach's alpha = 0.89.

5.2.4. Five-Facet Mindfulness Questionnaire (FFMQ). The FFMQ (Baer et al., 2006; 2008) is a 39-item questionnaire consisting of five subscales that measure five different facets of mindfulness: observing, describing, acting with awareness, non-judging of inner experience, and non-reactivity to inner experience (see Section 2.2). In the following, the five facets will be abbreviated as Obs, Descr, Act, Nonj, and Nonr respectively.

FFMQ items are rated on a 5-points Likert scale (1 = "never or very rarely true"; 5 = "very often or always true"); scores are calculated as the sum of the scores of the corresponding items. Obs, Descr, Act and Nonj are in the 8-40 range; Nonr is in the 7-35 range. Cronbach's alpha: Obs = 0.71, Descr = 0.92, Act = 0.84, Nonj = 0.86, Nonr = 0.75.

5.2.5. Name-Letter Task (NLT). Name-letter preference is a widely used and valid measure of self-esteem (Koole, Govorun, Cheng, & Gallucci, 2009). In NLT (Nuttin, 1985), letters are rated on a 7-point Likert scale (1 = “I do not like it at all”; 5 = “I like it very much”). We normalized NLT scores by employing the algorithm described in (LeBel & Gawronski, 2009). After sex, self-esteem is the most common moderator variable employed in TMT research (Burke et al., 2010), and thus NLT was one of the measures that we used to assign participants to the two experimental groups in a balanced way.

5.2.6. Locus of Control of Behavior (LCB) scale. The LCB scale (Rotter, 1966) includes 10 items for external LoC, and 7 items for internal LoC. Items are rated on a 6-point Likert scale (0 = “totally disagree”; 5 = “totally agree”). The external (resp. internal) LoC score is calculated from its 10 (resp. 7) items by summing their scores, and is in the 0-50 (resp. 0-35) range. From these scores, the general LoC score (0-85 range) is obtained by adding external LoC and the inverse of internal LoC. As reported in Section 2.2, LoC can affect individuals’ responses to MS cues. Therefore, LCB was one of the measures that we used to assign participants to the two experimental groups in a balanced way. Cronbach’s alpha: external LoC = 0.80, internal LoC = 0.66.

5.2.7. Risk Assessment Survey (RAS). The RAS (Miller & Mulligan, 2002) deals with 10 risky behaviors related to reckless driving, unprotected sex, drugs and alcohol consumption. Participants have to rate the perceived risk for them (i.e., how much risk of injury or illness would the participant be in, if (s)he engaged in a risky behavior), and the perceived risk for others (i.e., how much risk of injury or illness would others be in, if they engaged in a risky behavior). Items are rated on a 6-point Likert scale (1 = “slight risk”; 6 = “great risk”). The perceived risk to themselves (in the following, *RAS-self*) and the perceived risk to others (in the following, *RAS-others*) scores are calculated as the sum of the 10 item scores, and are in the 10-60 range. Cronbach’s alpha: pre-test RAS-self = 0.85, pre-test RAS-others = 0.87, post-test RAS self = 0.84, post-test RAS others = 0.86.

5.2.8. Physiological measures. We collected cardiovascular activity data employing a *photoplethysmograph* placed over the distal phalanx of the index finger of one hand, to record *blood volume pulse* (BVP). Increases in HR (calculated from BVP) are generally related to emotional activation (Andreassi, 2007), and anxiety (Kreibig, 2010). We also analyzed the BVP signal in the frequency domain, extracting the signal power in the high and low frequency bands (0.04-0.15 Hz and 0.15-0.40 Hz, respectively). We calculated LF power in normalized units of the LF band, and the LF/HF ratio. The value of LF in normalized units is a quantitative marker for sympathetic modulations, and LF/HF ratio is considered to reflect sympathetic nervous system modulation (Task Force of the European Society of Cardiology & The North American Society of Pacing and Electrophysiology, 1996).

5.2.9. Delay task questionnaire. TMT studies have to include a delay task, whose purpose is to allow for death thoughts to fade from consciousness yet remaining highly accessible (Burke et al., 2010). As reported in Section 2, changes in attitudes towards risk are related to distal defense processes, and the delay task is required in order for the study to gather information on distal rather than proximal defense processes. As a delay task, we asked participants to fill a PANAS (Watson, Clark, & Tellegen, 1988) questionnaire that comprises 20 words and phrases that describe different felt feelings and emotions, to be rated on a 5-point Likert scale (1 = "very slightly or not at all"; 5 = "extremely"). The data collected with this questionnaire were not analyzed because it served only the delay purpose.

5.2.10. Word Fragment Completion Task (WFCT). The WFCT is employed in the literature as MS manipulation check (Arndt et al., 1997; Harmon-Jones et al., 1997). The WFCT structure described by Arndt et al. (1997) comprises seven fragments of death-related words, and 19 filler word fragments. Word fragments are words missing one or more letters (e.g., "COFF _ _") that can be completed by participants by filling the blank spaces. Death-related fragments can be completed as either death-related words or neutral words (e.g., “COFFIN” or “COFFEE”), while filler fragments can be completed only as neutral words. We created a version of the WFCT in the participants’ first language, following the procedure described in (Arndt, Greenberg, & Cook, 2002). In particular, to choose the seven death-related fragments, we evaluated 16 fragments of death-related words through a pilot test involving a separate sample of 19 participants (13 M, 6 F; age: M = 34.89, SD = 13.53). The criterion indicated by Arndt and colleagues to consider a death-related fragment as suitable is that the fragment should not be completed with death-related target words more than 50% of the time in the pilot test. The 19 filler words were instead chosen among the most common nouns, adjectives and verbs, unrelated to death and mortality, in the participants’ first language.

WFCT score is calculated as the total number of death-related fragments completed with death-related words, and is thus in the 0-7 range.

5.3. Procedure

Participants were clearly informed that the collected experimental data was going to be analyzed anonymously for research purposes. Written informed consent for participation in the study was obtained. Before using the VE, participants had to fill the experimental questionnaires in the following order: demographic information, TCI, FFMQ, NLT, LCB, and RAS.

The results from the demographic questionnaire, NLT and LCB scales were employed to assign participants to the cemetery VE group (VE with MS cues; 48 F and 5 M) and to the park VE group (VE without MS cues; 47 F and 5 M) in a balanced way. We carried out independent samples t-tests to check that there were no statistically significant differences between the two groups resulting from the assignment. No differences were detected, and the results of the tests were the following:

- Mean age: 21.47 (SD = 2.78) in the cemetery VE group; 21.50 (SD = 2.08) in the park VE group; $t(103) = 0.06$, $p = 0.96$.

- Mean NLT score: 1.75 (SD = 1.41) in the cemetery VE group; 1.70 (SD = 1.28) in the park VE group; t(103) = 0.19, p = 0.85.
- Mean external LoC score: 18.58 (SD = 6.83) in the cemetery VE group; 18.69 (SD = 8.31) in the park VE group; t(103) = 0.07, p = 0.94.
- Mean internal LoC score: 22.89 (SD = 4.09) in the cemetery VE group; 23.02 (SD = 4.11) in the park VE group respectively; t(103) = 0.17, p = 0.87.
- Mean general LoC score: 30.70 (SD = 8.40) in the cemetery VE group; 30.67 (SD = 10.57) in the park VE group; t(103) = 0.01, p = 0.99.

Before wearing the HMD, participants were asked whether they preferred to hold the Nunchuck with the left or the right hand, and were free to try the device before answering. Two participants (one in the park VE group, one in the cemetery VE group) preferred to hold the Nunchuck with their left hand, the others preferred the right hand. After wearing the BVP sensor and the HMD, a simple VE was employed to adjust the HMD until participants could see well and feel comfortable with it, and to let participants practice with the controls. The simple VE reproduced a corridor that was initially straight, very large, and with no obstacles, but got narrower along the way, with an increasing number of curves and obstacles. To familiarize with the path markers (blue circles with white arrows), a number of them was placed along the corridor to indicate where to go. Participants were allowed to try the simple VE until they felt comfortable with the HMD and the controls. After that, they were instructed about the experimental task. They were told that:

1. They were going to watch a 2-min video with relaxing pictures and music. They were going to relax during the video, closing their eyes if they wished to;
2. Then, they were going to try a VE for 5 min. They were going to virtually walk in the VE, following a path marked by the blue circles; they could take their time during the exploration, looking around as they desired.

After receiving these instructions, participants relaxed while the 2-min video was played. During this time, we recorded the *baseline* for the physiological signals, i.e., the signals' values when the user is in a resting state. When analyzing physiological data, baseline data is needed to differentiate the physiological responses to experimental stimuli from the intrinsic physiological differences among participants. After baseline recording, participants were immersed in the interactive VE and, at the end of the 5-min task, the VE was stopped, and the HMD and physiological sensor were removed. Then, participants filled the delay task questionnaire, the RAS, and the WFCT questionnaire. Finally, they were debriefed about the experiment, and thanked for their participation.

5.4. Data analysis

The statistical analyses followed a between-subject design, with VE (cemetery or park) as the independent variable. The dependent variables were the following:

- WFCT scores;
- Post-test RAS-self scores;
- Post-test RAS-others scores;
- HRV LF data recorded during the task;
- HRV LF/HF data recorded during the task;
- HR data recorded during the task.

The analysis of WFCT scores was carried out using a two-sample t-test with Welch correction. For post-test RAS-self and RAS-other scores, we controlled for potential differences in individual pre-test questionnaire scores and pre-test physiological data by using one-way ANCOVA with pre-test questionnaire scores (respectively, pre-test physiological data) as the covariate and post-test questionnaire scores (respectively, physiological data during the VE task) as the dependent variable, as recommended in (Cohen, 2013) for dealing with a before-after mixed experimental design.

To evaluate the moderating effects of participants' personality traits (HA and mindfulness) on post-test RAS-self and RAS-others, in a series of additional analyses we defined independent variables for personality traits by performing a median-split of HA, Obs, Descr, Act, Nonj, and Nonr scores. Median-split was performed on the entire pool of participants, identifying participants below and above the median value. The independent variables defined by the median-split were:

- *HA level* (*low-HA* or *high-HA*);
- *Obs level* (*low-Obs* or *high-Obs*);
- *Descr level* (*low-Descr* or *high-Descr*);
- *Act level* (*low-Act* or *high-Act*);
- *Nonj level* (*low-Nonj* or *high-Nonj*);
- *Nonr level* (*low-Nonr* or *high-Nonr*).

For each of these independent variables, we performed a two-way ANCOVA involving the post- and pre-test RAS-self scores as dependent variable and covariate, respectively. RAS-others scores were subjected to the same ANCOVA analysis. In each of the two ANCOVAs, the second independent variable was VE. Unlike HA and mindfulness traits, LoC and self-esteem influence on responses to MS is known (see Section 2.2), therefore one needs to control for individual differences in these constructs that could potentially affect the post-test RAS scores. For this reason, we included two additional covariates (LoC and NLT) in the two analyses.

Finally, physiological variables (HR and HRV) were analyzed using one-way ANCOVA, with the baseline values (i.e., the mean values of physiological data recorded during the 2-min relaxation before the VE task) as the covariate, and the values recorded during the VE task as the dependent variable. VE was the independent variable.

6. Results

6.1. MS manipulation check

For the Word Fragment Completion Task (WFCT; Figure 7), the analysis revealed a significant difference between the two VE conditions, $t(98.33) = 3.34$, $p < 0.01$, two-tailed, 95% CI [0.20, 0.80].

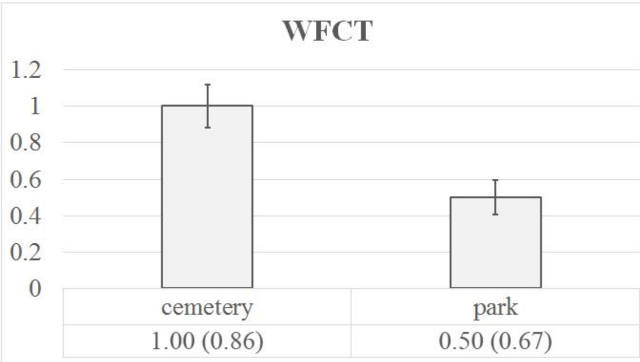

Figure 7. Means of WFCT scores (SD in brackets). Error bars indicate standard error of the mean.

6.2. Effects of VE on risk perception

Risk Assessment Survey (RAS) scores from a female participant in the park VE group were excluded because of an error during post-test RAS filling.

The analysis revealed significant differences between the two VE conditions for post-test scores of RAS-self ($F(1, 101) = 9.16$, $p < 0.01$, $\eta_p^2 = 0.08$) as well as RAS-others ($F(1, 101) = 7.64$, $p < 0.01$, $\eta_p^2 = 0.07$). Figure 8 shows mean values of RAS scores.

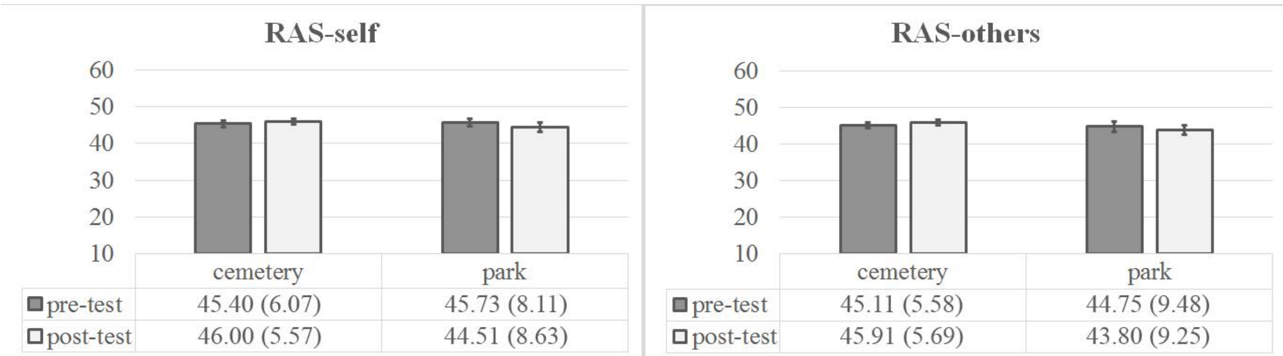

Figure 8. Means of RAS-self and RAS-others scores (SD in brackets). Error bars indicate standard error of the mean.

6.3. Interactions between personality traits and VE

6.3.1. Harm Avoidance. The analysis revealed that interaction between VE and HA for post-test RAS-self scores approached significance ($F(1, 97) = 3.56$, $p = 0.06$, $\eta_p^2 = 0.04$). It also showed a main effect of VE ($p < 0.01$), confirming the results reported before. The ANCOVA performed for RAS-others post-test scores showed a significant interaction between VE and HA ($F(1, 97) = 4.32$, $p < 0.05$, $\eta_p^2 = 0.04$). Post-hoc pairwise comparisons revealed that high-HA participants who used the cemetery VE reported a significantly higher risk perception for others than high-HA participants who used the park VE ($p < 0.01$); no significant difference has been instead observed for low-HA participants ($p > 0.05$). Figure 9 shows mean post-test RAS values considering the HA median-split.

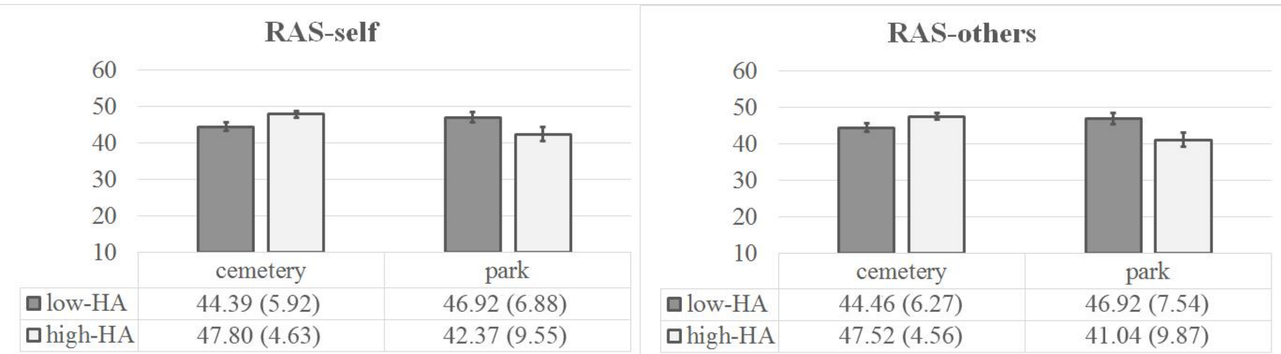

Figure 9. Means of post-test RAS-self and RAS-others (SD in brackets), calculated after pre-test HA median-splitting. Error bars indicate standard error of the mean.

6.3.2. Mindfulness. For post-test scores of RAS-self, the analysis showed a main effect of VE ($p < 0.01$), and no significant interaction between VE and Acting with Awareness (Act). For post-test scores of RAS-others, results revealed a main effect of VE ($p < 0.01$), and that the interaction between VE and Act approached significance ($F(1, 97) = 3.79$, $p = 0.06$, $\eta_p^2 = 0.04$).

Results showed a main effect of VE (all $p < 0.05$) no significant interaction between VE and Observing (Obs), Describing (Descr), Non-judging of inner experience (Nonj) and Non-reactivity to inner experience (Nonr) for either RAS-self or RAS-others (all $F(1, 97) < 3.39$, $p > 0.08$, $\eta_p^2 < 0.04$).

Figure 10 shows mean post-test RAS values considering the Obs, Descr, Act, Nonj, and Nonr median split.

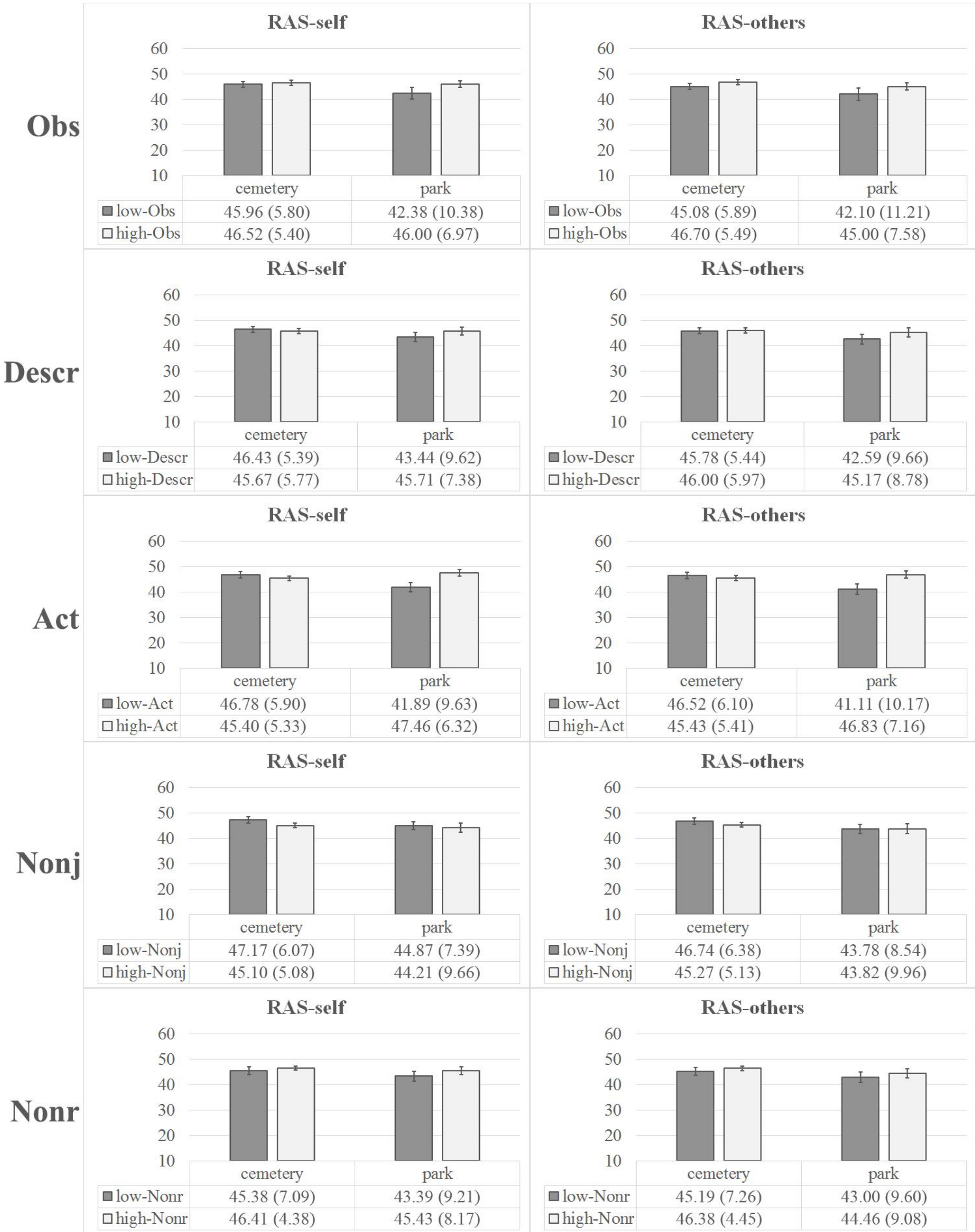

Figure 10. Means of post-test RAS-self and RAS-others (SD in brackets), calculated after the median-split of each pre-test score. Error bars indicate standard error of the mean.

6.4. Effects of VE on physiological response

Physiological data from a female participant in the park VE group were excluded due to a technical problem with the recording equipment.

The analysis showed significant differences between VE conditions in heart rate variability signal power values in the low-frequency band (HRV LF) ($F(1, 101) = 9.78$, $p < 0.01$, $\eta_p^2 = 0.09$), and in values of heart rate variability low frequency band/high frequency band power (HRV LF/HF) ratio values ($F(1, 101) = 9.44$, $p < 0.01$, $\eta_p^2 = 0.09$). Heart rate (HR) analysis did not show significant differences between VE conditions, $F(1, 101) = 0.17$, $p = 0.69$, $\eta_p^2 < 0.01$. Figure 11 shows mean HR values, mean LF values (expressed in normalized units) and mean values of the LF/HF ratio.

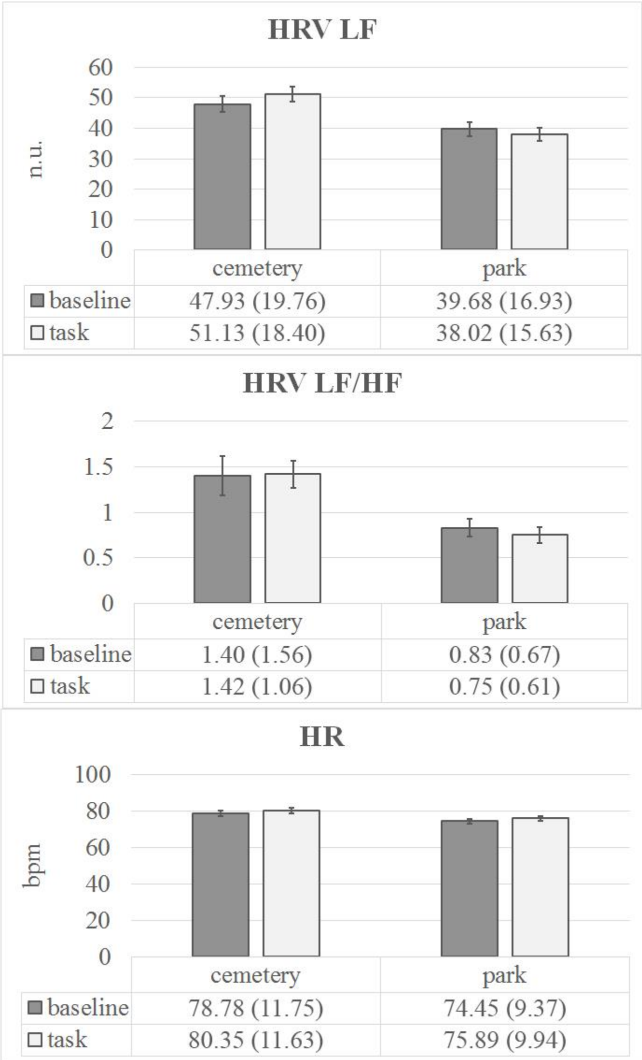

Figure 11. Means of HRV LF band power, HRV LF/HF ratio, and HR (SD in brackets). Error bars indicate standard error of the mean. Baseline means refer to the 2-min relaxation before the VE task.

7. Discussion

The significant difference between VE conditions in WFCT scores shows that the proposed VR-based MS manipulation was effective: the cemetery VE was able to elicit in participants a greater accessibility to death-related themes with respect to the park VE.

The significant differences pointed out by the analysis of RAS scores show that the cemetery VE was more effective than the park VE in affecting participants’ attitudes towards risk, enhancing their risk perception both for the self (RAS-self) and for others (RAS-others). These results are consistent with those in the TMT literature: Miller and Mulligan (2002) observed that MS elicited through a questionnaire enhances the perception of risk for the self and, for participants with an external orientation of LoC, also the perception of risk for others (in our study, we controlled for individual differences in LoC, see Section 5.3).

Our study elicited MS with a VR experience, while previous work that evaluated the impact of MS on attitudes towards risk employed instruments (e.g., Ben-Ari et al., 1999; Miller & Mulligan, 2002), described in Section 2.1.2, that are not conceived for practical inclusion in interactive applications. Showing that VR is able to elicit MS and obtain attitude change results as in traditional TMT studies opens new possibilities for the use of VR as a persuasive technology, and indicates a practical way to exploit TMT in building interactive applications for attitude change.

TCI and FFMQ scores in our study were useful to gain a deeper understanding of the moderating effects of personality traits on the results about participants' attitudes. Generally speaking, individuals with low HA scores tend to be carefree, relaxed and optimistic (Cloninger et al., 1993) and, similarly to individuals with low level of neuroticism (De Fruyt et al., 2000; Goldenberg et al., 2006), they are characterized by high levels of emotional stability. On the contrary, individuals with high HA scores, who can be described as worrying, pessimistic, fearful, and characterized by avoidance-oriented coping strategies (Cloninger et al., 1993; Ball, Smolin, & Sheckhar, 2002), were more strongly affected in their capability of perceiving and judging risks to others (RAS-others) by the presence or absence of MS cues in the VR experience. Our study results thus confirm the hypothesis that HA, similarly to neuroticism (Chauvin, Hermand, & Mullet, 2007), can be a moderating factor for risk perception. This is coherent with the fact that HA and neuroticism are positively correlated (De Fruyt et al., 2000). In RAS-self results, the interaction between HA and VE only approached significance, but the trend was consistent with RAS-others results (see Figure 9), suggesting that high levels of HA may also have an impact on the perceived risk for the self. The fact that we observed significant differences in risk perception between the cemetery and park VE in high-HA participants but not in low-HA participants suggests that participants' personality traits should be always taken into account when carrying out experiments that employ VR to affect user's attitudes towards risk, otherwise the results could reflect more the predominant traits in the groups than the intrinsic properties of the VEs.

The lack of significant interactions between VE and FFMQ subscales suggests that participants' mindfulness traits were not able to significantly moderate their attitude towards risk for the proposed VR-based MS manipulation. Only the interaction between Act and VE for RAS-others approached significance. We hypothesized that mindfulness should have influenced risk perception in the opposite direction with respect to HA, because the literature has shown that individuals characterized by high levels of trait mindfulness exhibit reduced defensive responses to MS cues (Niemiec et al., 2010). RAS-others results for the groups defined by the median-split of pre-test Act scores are in line with this hypothesis. To explain the lack of robust moderating effect of trait mindfulness on participants' attitudes towards risk, we can hypothesize that the immersion afforded by both VEs may have helped all participants, regardless of their mindfulness level, to focus on the assigned task, thus reducing the effects of the differences among participants with high and low mindfulness trait.

A general limitation of RAS results is that they measure the perception of risk concerning hypothetical behaviors that are not actually carried out by participants. Future studies could possibly try to allow participants to virtually act the risky behaviors mentioned in the RAS, using VR simulations after MS manipulation.

A limitation of our study is that the sample was composed by young individuals from a university population, most of them female: this may limit the generalizability of the observed results. Previous TMT research has suggested (Burke et al., 2010) that MS effects may be different (i.e., larger) for university students than older adults. In addition, women tend to be more risk averse than men (Burke et al., 2010). It could thus be interesting to extend the present study to older adults, and to samples with a larger percentage of men.

Considering physiological data, the significant differences in HRV shed some light on the effects of MS manipulation on an individual's physiology. The use of VR allowed us to observe a physiological reaction that traditional MS manipulations were not generally able to reveal. As reported in Section 1, the few studies in the literature that compared physiological arousal between conditions in which MS was elicited or not, were not able to obtain significant results. We employed LF power and LF/HF ratio, which are related to sympathetic nervous system activity, while Martens et al. (2010) measured parasympathetic-related features such as HRV HF power. They were able to find a positive relationship between vagal tone and self-esteem, a moderator for MS effects. However, to the best of our knowledge, our study is the first to establish a relationship between MS manipulation and arousal-related physiological responses. The results we obtained are in line with neuroimaging research (Quirin et al., 2012), which suggests that MS elicits the activity of brain regions related to arousal, such as the amygdala. HRV has been associated to amygdala activity in different general studies (Thayer, Åhs, Fredrikson, Sollers, & Wager, 2012). We can hypothesize that the use of an immersive VE may have increased these physiological responses to MS cues, helping to highlight physiological differences between experimental conditions.

According to the literature, VR experiences designed to elicit emotions can induce a higher sense of presence compared to more neutral ones (Baños et al., 2004), which in turn may significantly increase the effectiveness of any persuasive message included in it (Fox, Christy, & Vang, 2014). In our study, we did not assess participants' perceived sense of presence, and thus further studies are needed to examine possible effects of MS manipulation on presence, and possible mediating effects of presence on users' risk perception.

8. Conclusions

The study in this paper has shown that VR can be successfully employed to elicit MS, and that MS cues presented through an interactive VR experience can enhance user's risk perception both for the self and for others, paving the way to the use of TMT in VR-based persuasive technology. Unlike other studies in the literature (e.g., Arndt et al., 2001), we were also able to reveal an effect of MS manipulation on physiological correlates of arousal. Furthermore, we showed how some personality traits could moderate the effects of the VR experience on participants' attitudes towards risk: results suggest that high levels of the HA personality trait impact risk perception after MS elicitation, particularly when the risk involves other people.

To the best of our knowledge, the present study is the first that employs an immersive, interactive VE to manipulate MS. Furthermore, the observed results suggest that TMT is a useful tool to deepen the understanding of VR as a persuasive technology. In future studies, we plan to exploit TMT for the evaluation of different VR-based applications in which MS elicitation can be used for attitude change. For example, VR experiences designed for stress management training or emergency preparedness training include MS cues like the death of the user's avatar or other characters inside the VR experience as well as the destruction of familiar environments (e.g., Bouchard, Bernier, Boivin, Morin, & Robillard, 2012; Chittaro & Sioni, 2015). Exploiting TMT in the evaluation of these VR experiences may allow one to better understand their effects on users' attitudes towards the presented risks.

Given that commercial HMDs (Oculus Rift, HTC Vive, Sony PlayStation VR, Google Daydream, Samsung Gear) and immersive VR gaming have begun to reach the consumer market, making daily use of VR possible for the general public, future studies should evaluate how a repeated exposure to MS cues in immersive experiences can affect users' attitudes. In addition to VR experiences that include MS cues for attitude change purposes, it is worth noting that MS cues can appear in immersive video games simply to create a particular mood or atmosphere, with possible MS effects on users' attitudes unintended by designers. While the TMT literature as well as the results of our study indicate that MS elicitation, be it intended or unintended by the designer, would affect user's attitudes, one can also hypothesize that repeated use of the VR experiences might introduce a possible habituation to MS cues. Assessing if and how such possible habituation may reduce users' responses to MS cues is thus an important topic for further research.

Given the role of HMDs in enhancing users' immersion in virtual experiences, we also plan to compare the effects of MS cues presented by VR experiences characterized by different levels of immersion. In the VR literature, emotions related to high arousal levels such as fear and anxiety have been found to be stronger in highly immersive VR experiences compared to less immersive ones, see (Diemer, Alpers, Peperkorn, Shiban, & Mühlberger, 2015) for a review. Future studies should thus assess if a higher level of immersion could increase MS as well as the effects of MS elicitation in terms of death anxiety, risk perception and physiological responses. It would be also interesting to evaluate if and how users behave differently inside a highly immersive VR experience compared to a less immersive one. For example, users' movements inside the VE may be affected, and could be characterized by more avoidant behaviors towards the MS cues (e.g., walking at a greater distance from them or looking at them less frequently) as the level of immersion increases.

Finally, we plan to study the possible use of TMT in the evaluation of persuasive applications, e.g., mobile health apps, that do not use VR, and rely instead on written text or pictures to elicit MS. Examples of such MS cues in commercial applications are already available, e.g. Deadline (Gist, 2015) is an iPhone app that shows on screen an estimate of users' life expectancy calculated from the data collected by their mobile device (users' age, sex, physical activity…) with the intention of motivating them to live a healthy lifestyle.

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