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The impact of mortality salience on quantified self behavior during the COVID-19 pandemic

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ABSTRACT

Quantified self refers to the process consumers collect, analyze to reflect, control, and optimize their behaviors, thus obtaining self-knowledge. Since the COVID-19 pandemic has changed our lives dramatically, this research aims to explore how mortality salience caused by COVID-19 affects people's quantified self behavior. The current study used an online survey and the experimental method to test multiple research hypotheses. The results indicated that mortality salience has a positive impact on quantified self; perceived control mediates the relationship between mortality salience and the quantified self, and social distance plays a moderating role between mortality salience and perceived control. The conclusions provide a new way to help people deal with anxiety and fear brought by the COVID-19, and enhance public health and well-being.

1. Introduction

Since the outbreak of COVID-19, the virus has spread rapidly and greatly impacted all aspects of peoples' lives. Millions of people have been infected, and hundreds of thousands have died. These numbers are still increasing, which causes people to suffer from anxiety and fear of being infected or worry that this disease may tear them away from their loved ones. This global public health emergency has created multiple pressures and fears for people worldwide (Fofana et al., 2020). People now have to face economic and mental threats, such as fear of unemployment and other social problems such as food shortages, reduced safety, loneliness, depression, domestic violence (Campbell, 2020) and the overall uncertainty regarding the future (Paredes et al., 2021). Many people were compelled into panic-buying food, supplies, toilet paper, hand sanitizers, and even guns to feel safe (Dammeyer, 2020).

Terror management theory suggests that people will experience anxiety and fear when facing death (Greenberg et al., 1997). Greenberg proposed a terror management theory in which terror originates from people's thinking of death when human beings realize that "life is bound to end someday" (Greenberg et al., 1997; Solomon et al., 2004). The unpredictability and inevitability of death creates the fear of potentially losing human lives, causing people to fall into anxiety (Beck, 2004). People's awareness of death is called mortality salience, which is a core

concept of the theory. The phenomenon in which people take defensive actions after experiencing mortality salience is called the mortality salience effect, which is a process of terror management (Greenberg et al., 1994). Previous studies have revealed that exposure to mortality salience will reduce an individual's perceived control (Martin, 1999; Snyder, 1997). Perceived control is the extent to which an individual can predict, explain, influence, and change the occurrence and development of events (Raines et al., 2014). Losing a sense of control will lead to anxiety and other negative psychological outcomes (Whalen and Paul, 1998). These individuals will strive to regain a sense of control and develop compensatory behaviors (e.g., impulsive purchasing (Dammeyer, 2020) and indulgent behaviors (Ferraro et al., 2005)).

The quantified self is the process by which individuals use quantified tools (i.e., smartwatches, body fat scales, and quantified applications) to monitor their own bodies, states, and behaviors for self-reflection and self-knowledge acquisition (Choe et al., 2014). As this paper studies the threat of mortality salience to human beings and the change of human behavior (especially consumption behavior) it caused. In order to emphasize this, we use the word "consumer" in the paper. According to Sensor Tower (2021), in the second quarter of 2020, when the world is facing the first wave of COVID-19 outbreaks, quantified applications (such as fitness, diet, and nutrition) saw a surge of 530 million installs, then dropped to 330 million in the third quarter. Sales data revealed that

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the pandemic promoted the public's attention to their bodies (not just health) in their daily lives, thus enhancing people's quantified self behaviors. Therefore, we assume that mortality salience has an impact on quantified self behavior. Based on this, the current study aimed to explore the influence of mortality salience on consumers' quantified self behavior during the COVID-19 pandemic. It is expected that the results of this study will provide a way for people to better alleviate the negative psychological impacts of this global public health crisis and regain control and hope. This paper also seeks to offer theoretical contributions to the existing literature on mortality salience and quantified self behavior.

2. Theoretical background and hypotheses

2.1. Mortality salience and quantified self behavior

During the COVID-19 breakout, many people constantly watched COVID-19-related news to keep themselves up to date. The increasing numbers of infections and deaths stoked public fear and aggravated people's exposure to their mortality salience (Solomon et al., 1991). According to terror management theory, the awareness of mortality poses a serious threat to individuals (Florian et al., 2002). Facing the fear of death will arouse people's psychological defense mechanisms, further changing people's consumer behaviors (Arndt et al., 2004). Existing research has shown three core psychological defense mechanisms through which individuals alleviate existential anxiety: cultural worldview, self-esteem, and emotional attachment.

Cultural worldview refers to the explanation and belief of reality shared by most people. Through this belief system, people endow life with meaning, order, and immortality. It is as if as long as people abide by these beliefs, they can feel safe and life beyond death (Wisman, 2014). Influenced by their cultural worldviews, people tend to develop stronger connections, self-identification, and defenses among their ingroups (Vaes et al., 2010), which increases consumer preferences for domestic brands (Fransen et al., 2008; Friese and Hofmann, 2008; Liu and Smeesters, 2010). Another mechanism is self-esteem, which is a sense of self-worth obtained by individuals identifying and abiding by their cultural worldview (Solomon et al., 1991). When facing death, individuals will engage in more self-esteem striving behaviors to succeed in the cultural worldview values upon which their self-esteem is built. Previous research has revealed that, under a self-esteem defense condition, people will be more optimistic about their economic situation and more willing to spend on pleasurable items, such as clothing and entertainment, while sacrificing long-term interests to pursue more wealth and material possessions in the short term (Kasser and Sheldon, 2000). They will also become more interested in materialism, conspicuous consumption, and luxury goods to achieve a higher social status and self-worth (Guan et al., 2015; Kasser and Sheldon, 2000; Tambyah and Troester, 1999). Emotional attachment defense (Hart et al., 2005) refers to the mechanism for seeking togetherness, intimacy, closeness, and affiliation through establishing and maintaining a close relationship with others to alleviate death anxiety (Mikulincer et al., 2003). When facing death, individuals will naturally attach to people or things they are familiar with so as to overcome their psychological insecurity (Rindfleisch et al., 2009). Therefore, they will become more attached to their favorite brands and reduce the diversity of their product seeking behaviors (Thomson et al., 2005), which is consistent with the announcements of suppliers such as McDonald's that they are simplifying their menus, cutting down their product categories, and suspending new product development during the outbreak. Perceived mortality salience can also lead to informational conformity behaviors among consumers (Nicomedes and Avila, 2020). When someone rushes to acquire a drug that might allegedly be effective, others will soon join in the pursuit.

In addition to these three psychological defense mechanisms, researchers also noted that the effects of mortality salience on cultural defenses are mediated by group-based control restoration motivations,

such as supporting a cultural ingroup or seeking high levels of control (e.g., self-esteem) (Fritzsche et al., 2008). The cultural worldview and self-esteem defenses are built upon ingroups, where people share strong connections, closeness, and beliefs. Emotional attachment can also be seen as the need to belong to an ingroup. Under the threat of death, people defend, support, and relate to social ingroups to restore a sense of control via group membership (Fritzsche et al., 2008).

Usually, people have a generalized sense of control over their environment. However, certain events can deeply shake these beliefs. When people are exposed to mortality salience, the inevitability of death deprives them of ultimate control (Fritzsche et al., 2008), which increases anxiety and depression (Fiske and Morling, 1996). A personal sense of control is a limited resource, and loss of control will lead to a state of ego-depletion (Muraven and Baumeister, 2000). This is a primary human behavioral motivation that people will always strive to defend (Burger and Cooper, 1979), and the desire to regain perceptions of control plays an essential role in terror management processes (Dammeyer, 2020; Greenberg et al., 1997). It has been found that defending or maintaining a higher sense of control can promote well-being by reducing anxiety, depression, learned helplessness, and other mental disorders (Griffin et al., 2002; Rodin, 1986). Thus, people will develop compensatory behaviors to restore a sense of control.

Mortality salience exposure can lead to indulgent behaviors (Choe et al., 2014) as well as an increase in impulsive purchasing (Dammeyer, 2020) and the overall amount of purchasing and consumption among consumers (Mandel and Smeesters, 2008). After the terrorist attacks on September 11th, 2001 (9/11), Americans became more interested in luxury products (White et al., 2002) and bargains, hoarding canned goods, and excessively consuming sweets (Shawn, 2001). People engage in excessive consumption to cope with a loss of control caused by mortality salience (Arndt et al., 2004; Mandel and Smeesters, 2008). During the COVID-19 pandemic, many consumers have turned to do-it-yourself (DIY) projects and home-bound activities, such as cooking, baking, and gardening. People now cook more often than they have in the last 50 years (Taparia, 2020) and have become more confident in cooking (Hunter, 2020). Many consumers derive great pleasure, senses of achievement (Mochon et al., 2012), and pride (Colleen et al., 2015) from DIY projects and from sharing them with others (Belk, 2014), which is particularly important for individuals suffering control loss in other life domains due to the pandemic (Kirk and Rifkin, 2020). In summary, people tend to seek diversified compensatory behaviors to restore a sense of control so as to reduce the influence of their control loss.

Quantified self behavior is one of the compensatory behaviors that can help people gain a more personal sense of control. With the emergence and promotion of wearable devices (e.g., Apple Watch and Fitbit) and smart applications (e.g., Adidas Runtastic and MyFitnessPal), consumers' quantified self behaviors have become more convenient. As a widespread practice, the application of the quantified self is not limited to the field of health (e.g., diet, fitness, and sleep) but also related to time management, travel, social interactions, and consumption (Brophy-Warren, 2008). With the help of digital technology, sensory-friendly designs (Lv et al., 2020a; Lv et al., 2020b), and cloud-based services, consumers can now utilize smart applications and equipment to accurately reflect, control, and optimize their behaviors. They can also better understand and improve their health, performance, and life status by tracking and analyzing their daily activities and physiological function data, thus achieving a more cognitive, predictable, and manageable life status (Moore and Robinson, 2016). Moreover, quantified self can improve consumers' perceptions of deadlines and help develop a more reasonable daily schedule to achieve their goals with better performance. This helps consumers regain a sense of control (Ruckenstein, 2014). Furthermore, the quantified self enables consumers to form self-knowledge more strongly based on recognizable quantitative data and make exact behavior decisions, rather than decisions based on subjective experiences and feelings (Lupton, 2014), thereby realizing accurate and

rational behaviors. Quantitative monitoring data, such as objective digital evidence and statistical data, provide precise control and some extent of predictability, which can produce a sense of security and certainty (Lupton and Deborah, 2013), thus compensating for control loss.

The quantified self is widely used in the fields of sports and fitness. Athletes have long been engaged in self-monitoring exercises to improve their performance and make better training plans (Saw et al., 2015). For ordinary daily fitness, wearable devices and quantified self applications make self-tracking accessible, especially for heart rate, energy intake, and consumption, which are among the most popular applications. These technologies can also manage emotions. Moodscope, created by Jon Cousins (Moodscope), uses emotion cards to collect and analyze users' emotional states with visualization charts. Users can share their data with friends and doctors to help better manage their emotions. Quantified self is also of great significance to personal healthcare and modern medicine. Some health social networks (e.g., PatientsLikeMe) provide sophisticated visualizations of patients' conditions, symptoms, treatments, and other biological information, which are very helpful in monitoring chronic disease. For example, according to the International Diabetes Federation Diabetes Atlas (2020), the number of diabetes patients worldwide has reached 463 million, which is equivalent to 1 patient in 11 people. The quantitative management of blood sugar is vital for disease control. The quantified self promotes the accurate monitoring and comprehensive understanding of personal health conditions and has facilitated the arrival of a patient-driven era in the medical field (Appelboom et al., 2014). In the workplace, the quantified self can help improve leaders' self-awareness, self-regulation, self-motivation, and manage stress and fatigue through assessment and feedback (Ruderman and Clerkin, 2020), thus allowing individuals to gain greater control over their performance and have a better career.

In conclusion, when facing the fear of death during the pandemic, people will suffer control loss and seek compensation. The COVID-19 pandemic has profoundly changed our lifestyles, and its impact may last for years. To the best of our knowledge, how this new environment, particularly mortality salience, influences quantified self behavior and its mechanisms remains unexplored. By promoting consumers' self-monitoring activities, the quantified self arouses consumers' self-awareness (Moore and Robinson, 2016) and self-enhancement, which yields a sense of certainty and control, making consumers more able to control complex and uncertain situations (Lupton and Deborah, 2013) and further helping people attain a greater sense of control in various aspects of their lives. When threatened by mortality salience, the loss of control promotes quantified self behavior, which is essentially an optimization of self state.

Therefore, we hypothesize that:

Hypothesis 1. Mortality salience has a positive effect on quantified self behavior.

Hypothesis 2. Mortality salience has a negative effect on perceived control.

Hypothesis 3. Perceived control mediates the relationship between mortality salience and quantified self behavior.

2.2. The moderating role of social distance

Social distance is a dimension of psychological distance. Other dimensions include time distance, space distance, and hypothetical distance (Trope et al., 2007). Psychological distance is a core concept of construal level theory, which affects consumers' psychology and behavior by changing people's cognition and mental construal. According to Park (1924), social distance refers to "the grades and degrees of understanding and intimacy which characterize personal and social relations generally." It represents the degree of an individual's willingness to accept others into his or her relationships (Park, 1924)—that is, the extent to which people interact with others whom they perceive to

be psychologically close to themselves (Kwon, 2019). According to seven different degrees of closeness, Bogardus developed a scale to measure people's willingness to interact with others, ranging from no distance—"accepting others as close relative by marriage"—to maximum distance "excluding others from entry into your country" (Bogardus, 1933). There are also other ways to measure social distance (e.g., frequency and length of interactions, offline and online contacts, and degree of imitation) (Joo et al., 2018).

With the COVID-19 pandemic sweeping the globe, many countries have issued administrative orders to mandate travel bans and social distancing to prevent the spread of the virus. Almost one third of the world's population was quarantined due to the contagious viral disease (Bashir et al., 2020), while in China, community lockdown bans were exceptionally strict. No gatherings were allowed. Home quarantine and lockdown greatly increase the (offline) social distance between people. Universities adopted online and remote teaching, and many companies encouraged their staff to work from home. As the "new normal", the circle of socialization will undoubtedly shrink. Social ties and traditional networks were insufficient, such as infrequent visits or calls with family or friends. Therefore, online social media (e.g., Skype, WeChat, Line, and Facebook) have become vital in creating and maintaining social contacts and reducing the social distance between people (Lev-On and Lissitsa, 2015). However, in terms of perceived closeness, online communication is generally weaker than in-person communication. For example, when a person is upset, he or she cannot feel a hug from a friend on screen. As we are social beings, quarantine and isolation mean fewer outdoor physical activities (Swami et al., 2021), recreational activities, and visits with relatives and friends, which may pose considerable risks for health and wellbeing (Khan et al., 2020; Lev-On and Lissitsa, 2015; Paredes et al., 2021). Feelings of loneliness were proven to be related to poor cognitive performance and sensitivity to social threats (Cacioppo and Hawkey, 2009). Moreover, people under community lockdown tend to develop various psychological problems, such as stress, depression, and fear (Brooks et al., 2020), which aggravate the personal control loss caused by mortality salience. Especially for those who live alone, their chance to interact with others was deprived. Larger social distance in the context of the COVID-19 pandemic means that such individuals will suffer greater control loss. More than 77 million adults live alone in China; in developed countries, the numbers are even higher (China Statistical Yearbook, 2019). The psychological problems of such a large solitary population should not be ignored. Thus, the importance of maintaining social interactions is especially salient at this time.

Some scholars have studied the impact of social distance. Oosterhoff et al. explored adolescents' motivations for social distancing and their relationships with mental health and social health (Oosterhoff et al., 2020). The authors found that adolescents who live with their parents reported greater belongingness (less social distance) mainly because of their parents' companionship, love, and caring. Social distance can affect people's decision-making processes. Decreasing social distance also leads to a reduction in risk-taking behaviors (Montinari and Rancan, 2018). Florian revealed that reducing people's sense of belonging and closeness through relationship threats like separation can lead to a stronger sense of control loss caused by mortality salience (Florian et al., 2002). Cox noted that perceived closeness can also reduce the accessibility of death-related thoughts (Cox and Arndt, 2012). Bogardus developed a social distance measurement scale based on the degree of perceived closeness (Bogardus, 1933). From the studies discussed above, we can deduce that quarantine isolation can make it difficult for an individual to compensate for a loss of sense of control through interpersonal interactions, which aggravates the negative effect of mortality salience on perceived control. The lonelier people are, the fewer interpersonal interactions they can obtain, and the lower their perceived control will be.

Thus, the following hypothesis is formulated:

Hypothesis 4. Social distance moderates the relationship between mortality salience and perceived control. When being more socially distant, mortality salience has a stronger negative effect on perceived control; when being socially closer, mortality salience has a weaker negative effect on perceived control. The conceptual framework see Fig. 1.

3. Methods

3.1. Study 1

3.1.1. Design and data

An online survey was conducted on Sojump.com (the largest online survey website in China), considering the COVID-19 pandemic. The purpose of this study is to preliminary verify the hypothesis through people's actual quantified-self data during the COVID-19. Four hundred questionnaires were distributed, and 323 were returned. Finally, 271 completed samples remained for a valid return rate of 67.8%. Demographic characteristics results showed that 45% were male, 18–35 years old accounted for 62.7%; college degree accounted for 83.0%, and monthly income range from CNY 5000-17,000, accounted for 66.1%. No participants got infected. The demographic characteristics is shown in Table 1.

3.1.2. Measurement

The measurement items were all from the existing scales, and the content of some items has been adjusted to the research situation. Referring to the research of Martens et al. (2011), we measured mortality salience (Templer, 1970). There are 15 items, including six reverse questions, we adjusted them to positive questions, including “When it comes to COVID-19, I am very much afraid to die”, “When it comes to COVID-19, the thought of death often hits my mind”, and so forth. Three items scale adapted from Liu et al.'s study (2016) was used to measure perceived control (Liu et al., 2016). And one item scale adapted from Lev-On and Lissitsa (2015) to measure perceived social distance (Lev-On and Lissitsa, 2015). All measures in this study (see Appendix 1) were scored on a 7-point Likert scale (1 = not at all, 7 = very much). For social distance, 1 point stands for no contact with others, which means the social distance is very distant, 7 points stands for very frequent contact, which means the social distance is very close. Multiple choice questions (at least one answer) were used to measure the quantified self behavior. First, we presented the definition of the quantified self, then asked the participants about their use of quantified self products and applications (Lv et al., 2020c) during the COVID-19 outbreak. In the questionnaire, we list quantified self products sold on Amazon and common in consumers' daily life, including “body fat scales or electronic scales”, “smart bands or smartwatches”, “blood pressure or blood glucose monitors”, “treadmill, rowing machines, etc. with digital statistical display screen”, “environmental monitoring equipment such as thermometer, hygrometer, and formaldehyde testers”, and so forth. Besides, participants can also fill in other quantitative products they use. Similarly, we presented quantified self applications on Apple store that are common in their daily lives, including applications recording dietary calorie intake such as “myfitness pal”, monitoring running mileage, and speed such as “Adidas runtastic”, etc. Participants can also fill in other quantified self applications they use but did not appear in the above list. One score will

Table 1
Demographic characteristics.

Characteristics		Frequency	Percentage
Gender	Male	122	45.0%
	Female	149	55.0%
Age	Below 18	4	1.5%
	18–25	61	22.5%
	26–35	109	40.2%
	36–45	73	26.9%
	46–60	16	5.9%
Education	Above 60	8	3.0%
	College degree and below	116	42.8%
	Bachelor's degree	109	40.2%
Income	Postgraduate degree and above	46	17.0%
	Below 5000	70	25.8%
	5001-8000	98	36.2%
	8001-17,000	81	29.9%
	17,001-30,000	14	5.2%
	30,000 and above	8	3.0%

be given for each item of quantified self product or application, and 0 point will be given if it has not been used. Finally, the scores of quantified self products and applications usage reflected consumers' quantified self behavior.

3.1.3. Results

3.1.3.1. Reliability and validity. SPSS 22.0 was used for reliability analyses and AMOS 24.0 was used for validity test (CFA). The results showed that Cronbach's α coefficients were all greater than 0.7, mortality salience ($\alpha = 0.93$) and perceived control ($\alpha = 0.82$), which indicated that the scale had high internal consistency and good reliability. Confirmatory factor analyses showed that the model fit was adequate: ($\chi^2/df = 1.887$, RMSEA = 0.058 < 0.08, GFI = 0.902 > 0.9, CFI = 0.921 > 0.9, IFI = 0.921 > 0.9, TLI = 0.909 > 0.9). The standardized factor loadings of all items were greater than 0.75, the composite reliability of mortality salience and perceived control were 0.96 and 0.93 respectively, and AVE values were 0.68 and 0.81, which exceeded the cut-off value of 0.5, indicating a high convergent validity. The square root of AVE were greater than the correlation coefficients between the two variables (0.79), indicating good discriminative validity (see Table 2).

The statistical approach was utilized to assess common method bias. Harman's single-factor test was used to analyze the variance proportion of a single factor (Podsakoff, 2003). The factor analysis with an unrotated factor solution showed that about 38.1% of the total variance (not exceeding the threshold of 50%) was accounted for by a single factor. Thus, this was evident that the common method variance is not a significant concern in the present study.

Table 2
Descriptive statistics and correlations of the constructs.

Variables	Mean	SD	1	2	3	4
1. Mortality salience	4.85	1.065	0.83			
2. Perceived control	3.53	1.300	-0.79***	0.90		
3. Quantified self products	2.20	1.009	0.34***	-0.36***	-	
4. Quantified self applications	3.45	1.954	0.33***	-0.39***	0.53***	-
5. Social distance	4.98	1.235	0.20*	0.05	-0.10	-0.14*

Note: $n = 271$; SD = standard deviation; values on the diagonal represent the square root of the average variance extracted; * indicates $p < 0.05$, ** indicates $p < 0.01$, *** indicates $p < 0.001$.

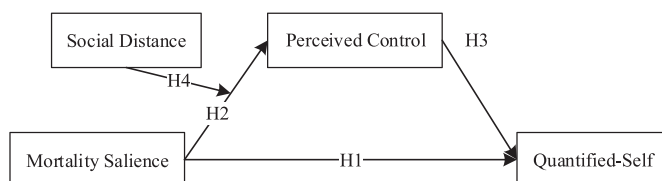


Fig. 1. Conceptual framework.

3.1.3.2. Dependent variable. Take gender, age, education level, and monthly income as control variables, mortality salience as an independent variable, and quantified self products as the dependent variable. Regression results showed that the overall model fit was adequate: ($F = 7.963, p < 0.001, R^2 = 0.131$). The impact of mortality salience on quantified self products was significant ($\beta = 0.345, t = 5.963, p < 0.001$). Gender ($\beta = 0.011, t = 0.194, p = 0.846$), age ($\beta = 0.055, t = 0.939, p = 0.348$), education level ($\beta = 0.004, t = 0.073, p = 0.942$), and monthly income ($\beta = 0.101, t = 1.730, p = 0.085$) had no significant effect. Similarly, take quantified self applications as the dependent variable, regression results revealed that the overall model fit was adequate: ($F = 7.868, p < 0.001, R^2 = 0.129$). The effect of mortality salience on quantified self applications was significant ($\beta = 0.337, t = 5.825, p < 0.001$). Also, gender ($\beta = -0.030, t = -0.525, p = 0.600$), age ($\beta = -0.062, t = -1.058, p = 0.291$), education level ($\beta = 0.015, t = 0.248, p = 0.805$), and monthly income ($\beta = -0.098, t = -1.677, p = 0.095$) had no significant effect. **H1** was preliminarily verified.

3.1.3.3. Mediating effect. The same method is used to test the effect of mortality salience on perceived control. Results showed that the impact of mortality salience on perceived control was significant ($\beta = -0.816, t = 20.661, p < 0.001$). Gender ($\beta = 0.001, t = 0.004, p = 0.998$), age ($\beta = 0.054, t = 1.457, p = 0.146$), education level ($\beta = -0.014, t = -0.383, p = 0.702$), and monthly income ($\beta = 0.023, t = 0.620, p = 0.536$) had no significant effect. Thus supporting **H2**.

When the dependent variable is quantified self products, the mediating effect of perceived control is significant ($\beta = 0.194, \text{Boot SE} = 0.088, 95\% \text{ CI} = [0.017, 0.361]$, not included 0). After controlling the mediating effect, the effect of mortality salience on quantified self products was no longer significant ($\beta = 0.132, \text{SE} = 0.093, 95\% \text{ CI} = [-0.050, 0.315]$, included 0), indicating that perceived control played a fully mediating role. When the dependent variable is quantified self applications, the mediating effect of perceived control is significant ($\beta = 0.498, \text{Boot SE} = 0.185, 95\% \text{ CI} = [0.119, 0.838]$, not included 0). After controlling the mediating effect, the effect of mortality salience on quantified self applications was no longer significant ($\beta = 0.120, \text{SE} = 0.178, 95\% \text{ CI} = [-0.231, 0.471]$, included 0), indicating that perceived control played a fully mediating role. Thus supporting **H3**.

3.1.3.4. Moderating effect. Bootstrapping method was used to test the moderating effect of social distance. (PROCESS, Model 7, 5000 samples, 95% confidence interval, see [Table 3](#)). The results showed that the main effect of mortality salience on perceived control was significant ($\beta = -0.684, \text{SE} = 0.177, 95\% \text{ CI} = [-1.033, -0.335]$, not included 0), and the main effect of social distance on perceived control was significant ($\beta = 0.592, \text{SE} = 0.177, 95\% \text{ CI} = [0.244, 0.941]$, not included 0), and the interaction effect between mortality salience and social distance was significant ($\beta = -0.072, \text{SE} = 0.034, 95\% \text{ CI} = [-0.140, -0.005]$, not included 0). When the dependent variable was quantified self products, the direct effect of mortality salience was not significant ($\beta = 0.132, \text{SE} = 0.093, 95\% \text{ CI} = [-0.050, 0.315]$, included 0), the mediating effect of

perceived control increased with social distance: when social distance is one standard deviation lower than the mean value (-1 SD), the effect was 0.189 ($\text{Boot SE} = 0.086, 95\% \text{ CI} = [0.021, 0.360]$, not included 0); when social distance is equal to the mean value, the effect was 0.204 ($\text{Boot SE} = 0.092, 95\% \text{ CI} = [0.023, 0.384]$, not included 0); when social distance is one standard deviation greater than the mean value ($+1 \text{ SD}$), the mediating effect was 0.218 ($\text{Boot SE} = 0.098, 95\% \text{ CI} = [0.024, 0.409]$, not included 0) ([Fig. 2](#)).

Similarly, when the dependent variable was quantified self applications, the direct effect of mortality salience was not significant ($\beta = 0.120, \text{SE} = 0.178, 95\% \text{ CI} = [-0.231, 0.471]$, included 0), the mediating effect of perceived control increased with social distance: when social distance is one standard deviation lower than the mean value (-1 SD), the effect was 0.487 ($\text{Boot SE} = 0.179, 95\% \text{ CI} = [0.130, 0.838]$, not included 0); when social distance is equal to the mean value, the effect was 0.523 ($\text{Boot SE} = 0.191, 95\% \text{ CI} = [0.137, 0.898]$, not included 0); when social distance is one standard deviation greater than the mean value ($+1 \text{ SD}$), the mediating effect was 0.559 ($\text{Boot SE} = 0.205, 95\% \text{ CI} = [0.145, 0.954]$, not included 0). Therefore, **H4** was supported.

3.1.4. Discussion

First, Study 1 initially verified the effect of mortality salience on quantified self during the COVID-19 pandemic; that is, mortality salience positively affects quantified self behavior (**H1**). Second, it preliminarily verified the mediating role of perceived control (**H2, H3**). It is found that mortality salience increases quantified self behavior by weakening people's perceived control. Finally, we verified the moderating effect of social distance between the relationship of mortality salience and perceived control (**H4**). Specifically, when the social distance is more distant, mortality salience has a stronger negative effect on perceived control; when the social distance is closer, mortality salience has a weaker negative effect on perceived control.

The survey was conducted during the most severe period of the COVID-19 pandemic in China. In the case of strict home quarantine, the threat of the pandemic has brought great impact, making the participants feel helpless and powerless. Therefore, there is a high correlation between mortality salience and perceived control. Meanwhile, the cross-sectional data of survey may further aggravate this problem. In view of this, in Study 2 was conducted after the home quarantine was cancelled, and we used the experimental method to solve this problem.

3.2. Study 2

3.2.1. Design

To control other possible interference factors, Study 2 used an experimental method to test research hypotheses under more stringent conditions. A single-factor between-subjects design (mortality salience: high vs. low) was conducted in this study. According to Martens ([Martens et al., 2011](#)), by reading a news report about death or pain symptoms caused by COVID-19, we manipulated the participants' perceived mortality salience. In the case of high mortality salience, the news report describes death. "Since the COVID-19 outbreak, the global death toll has

Table 3
Outputs of bootstrap test in Study 1.

Outcome	Moderator (Social distance)	Effect	SE	t	p	95% CI	
						LI CI	UI CI
Perceived control	Mortality salience × Social distance	-0.072	0.034	-2.11	0.036	-0.140	-0.005
Quantified self products	MO: -1 SD, 3.74	0.189	0.086 ^a			0.021 ^a	0.360 ^a
	MO: Mean, 4.98	0.204	0.092 ^a			0.023 ^a	0.384 ^a
	MO: +1 SD, 6.21	0.218	0.098 ^a			0.024 ^a	0.409 ^a
	MO: -1 SD, 3.74	0.487	0.179 ^a			0.130 ^a	0.838 ^a
Quantified self applications	MO: Mean, 4.98	0.523	0.191 ^a			0.137 ^a	0.898 ^a
	MO: +1 SD, 6.21	0.559	0.205 ^a			0.145 ^a	0.954 ^a

Note: MO stands for moderator.

^a Indicates for estimation by bootstrap.

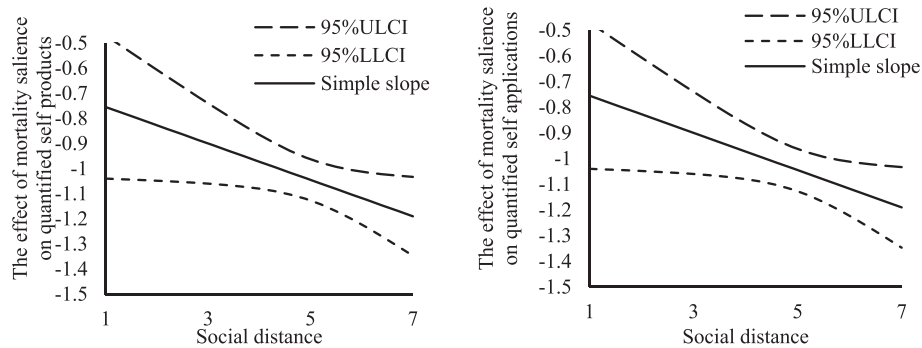


Fig. 2. The result of float light analysis.

exceeded 700 thousand. In some countries, their health care systems were on the verge of collapse, and doctors were forced to choose whom to save..." In the case of low mortality salience, it describes, "Since the COVID-19 outbreak, the number of infections worldwide has reached 18.81 million. Patients usually suffered recurrent high fever, muscle pain, and strong side effects of drugs..."

3.2.2. Pretest

A pretest was conducted with 73 graduate students (50.7% female; Mage = 23.10, SD = 1.780) to verify our manipulation. Participants were randomly assigned to two between-subject groups (mortality salience: high vs. low). After reading the material, we measured the mortality salience. After controlling the impact of gender and age, a one-way ANCOVA analysis showed that compared with the low mortality salience group, the high mortality salience group ($M_{\text{high}} = 5.73$, $M_{\text{low}} = 5.27$, $F(1,71) = 4.520$, $p = 0.037$) had significantly higher mortality salience perception ($\alpha = 0.91$). The materials are properly designed.

3.2.3. Participants and procedure

One hundred sixty-seven participants (52.7% female; Mage = 34.87, SD = 8.800) from Sojump (China's largest online survey platform) were randomly assigned to two conditions. No participants get infected. In order to avoid the anxiety caused by the unskilled use of digital devices and applications, which further affects the experimental results, only the users who can skillfully use mobile devices and applications were selected as participants. The participants were asked to read mortality salience material and then finish the measurement items of mortality salience, perceived control, social distance (same as Study 1). The participants were asked about their intention to use quantified self products and quantified self applications. According to the results of Study 1, we chose a smart band and fitness application that people are familiar with as examples. After a brief introduction to the product/application functions, we asked about their willingness to use the product/application. (7-points scale, 1 = very reluctant, 7 = very willingly).

3.2.4. Results

3.2.4.1. Manipulation checks. One-way ANCOVA analysis revealed that, for perceived mortality salience ($\alpha = 0.93$), compared with the low mortality salience group, the high mortality salience group had significantly higher perceived mortality salience ($M_{\text{high}} = 5.54$, $M_{\text{low}} = 5.02$, $F(1,165) = 6.446$, $p = 0.012$). Thus, the manipulation was successful.

3.2.4.2. Dependent variable. A one-way ANCOVA on participants' willingness to use yielded a significant main effect for mortality salience. For the high mortality salience group, the willingness to use smart band or application was significantly higher than that of the low mortality salience group (smart band: $M_{\text{high}} = 5.25$, $M_{\text{low}} = 4.86$, $F(1,165) = 5.256$, $p = 0.023$; fitness application: $M_{\text{high}} = 5.51$, $M_{\text{low}} = 4.98$, $F(1,165) = 9.644$, $p = 0.002$). **H1** was supported.

3.2.4.3. Mediating effect. For perceived control ($\alpha = 0.87$), the high mortality salience group was significantly lower than that of the low mortality salience group ($M_{\text{high}} = 3.01$, $M_{\text{low}} = 3.88$, $F(1,165) = 5.843$, $p = 0.017$). **H2** was supported. A bootstrap method (PROCESS, model 4, 5000 samples, Hayes, 2013) was used to test the mediating effect of perceived control (mortality salience: 0 = low mortality salience, 1 = high mortality salience). Results showed that after controlling two covariate variables (gender and age), the indirect effect of perceived control was significant (smart band: $\beta = 0.554$, Boot SE = 0.139, 95% CI = [0.296, 0.839], not included 0; fitness application: $\beta = 0.550$, Boot SE = 0.142, 95% CI = [0.279, 0.841], not included 0). **H3** was verified.

3.2.4.4. Moderating effect. A bootstrap method (PROCESS, model 7, 5000 samples, Hayes, 2013) was conducted to test the moderating effect of social distance. Results showed that, after controlling two covariate variables (gender and age), the interaction between mortality salience and social distance on perceived control was significant ($\beta = -0.308$, SE = 0.139, 95% CI = [-0.582, -0.035], not included 0) (see Table 4).

For the willingness to use smart band, when the social distance was -1 SD, the effect was 0.012 (Boot SE = 0.141, 95% CI = [-0.277, 0.280], included 0); when the social distance was equal to the mean value, the effect was 0.272 (Boot SE = 0.118, 95% CI = [0.040, 0.508], not included 0); when the social distance was $+1$ SD, the mediating effect was 0.533 (Boot SE = 0.198, 95% CI = [0.150, 0.926], not included 0).

For the willingness to use fitness application, when the social distance was -1 SD, the effect was 0.011 (Boot SE = 0.142, 95% CI = [-0.264, 0.297], included 0); when the social distance was equal to the mean value, the effect was 0.270 (Boot SE = 0.119, 95% CI = [0.048, 0.519], not included 0); when the social distance was $+1$ SD, the mediating effect was 0.528 (Boot SE = 0.199, 95% CI = [0.152, 0.936], not included 0). Therefore, **H4** was verified (Fig. 3).

3.2.5. Discussion

In order to control other potentially influencing factors, Study 2 used a scenario simulation experiment to verify the impact of mortality salience on quantified self behavior (including the willingness to use quantified self products and quantified self applications). When facing high mortality salience, people's quantified self willingness is significantly higher than that of low mortality salience, and perceived control plays a mediating role. Social distance plays a moderating role in the relationship between mortality salience and perceived control. When the social distance is distant, mortality salience has a stronger negative effect on perceived control; when the social distance is close, mortality salience has a weaker negative effect on perceived control.

Table 4
Outputs of bootstrap test in Study 2.

Outcome	Moderator (Social distance)	Effect	SE	t	p	95% CI	
						LLCI	ULCI
Perceived control Smart band	Mortality salience × Social distance	-0.308	0.139	-2.22	0.028	-0.582	-0.035
	MO: -1 SD, 2.25	0.012	0.141 ^a			-0.277 ^a	0.280 ^a
	MO: Mean, 3.53	0.272	0.118 ^a			0.040 ^a	0.508 ^a
Fitness application	MO: +1 SD, 4.82	0.533	0.198 ^a			0.150 ^a	0.926 ^a
	MO: -1 SD, 2.25	0.011	0.142 ^a			-0.264 ^a	0.297 ^a
	MO: Mean, 3.53	0.270	0.119 ^a			0.048 ^a	0.519 ^a
	MO: +1 SD, 4.82	0.528	0.199 ^a			0.152 ^a	0.936 ^a

Note: MO stands for moderator.

^a Indicates for estimation by bootstrap.

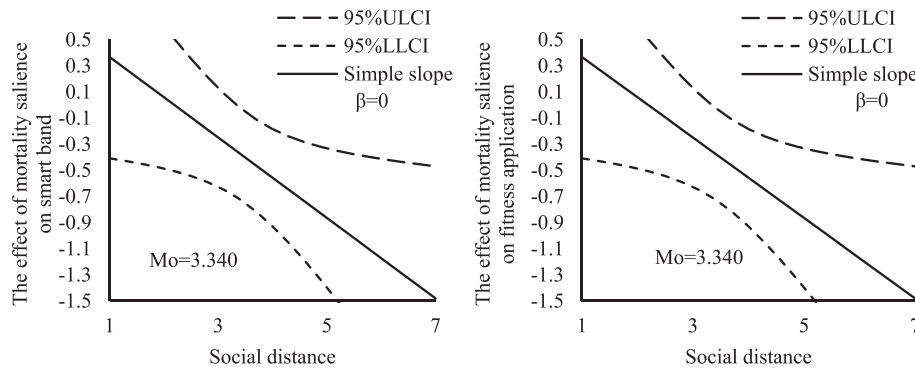


Fig. 3. The result of float light analysis.

4. Discussion

4.1. Theoretical contributions

The current study explained how the mortality salience caused by global public health emergencies can influence an individual's quantified self behavior in the context of COVID-19, as well as its underlying mechanisms, and how social distance moderates this effect.

First, this paper explored a new way of dealing with mortality salience and a personal sense of control loss. Facing the deaths caused by the COVID-19 pandemic will reduce individuals' perceived control. As the quantified self can produce various aspects of accurate control in one's life, it is able to compensate for the control loss caused by mortality salience. Therefore, mortality salience increases quantified self behavior. This finding enriches and expands the research on quantified self behavior and aligns with previous literature showing that people tend to develop compensatory behavior (e.g., purchasing utilitarian products (Chen et al., 2017) and increasing charitable contributions (Xu et al., 2020)) when suffering control loss.

Second, this paper found that the core mechanism of mortality salience on the quantified self is a personal sense of control loss. The COVID-19 pandemic has created a highly uncertain environment, which reduces an individual's sense of control. Both mortality salience and social distance affect quantified self behavior through perceived control.

Last, this paper identified the moderating effect of social distance. When facing mortality salience, people will seek emotional attachment to compensate for their control loss. Greater social distance means a poorer sense of belonging and closeness, which can aggravate the anxiety and fear of mortality salience, thus weakening perceived control and enhancing the need for quantified self behavior. This result is consistent with previous studies on the effect of emotional attachment on mortality salience.

4.2. Practical implications

This research provides several practical implications for public administrations during the COVID-19 pandemic.

First, the mortality salience produced by the pandemic makes people feel anxious about losing their sense of control. Moreover, the current study revealed that greater social distance between people could aggravate the effect of mortality salience on perceived control loss. After COVID-19 infections and deaths had climbed to record highs, the director-general of the World Health Organization, Tedros Adhanom Ghebreyesus, claimed that the pandemic's lack of social interaction profoundly affected people. Nearly 1 billion people currently suffer from mental disorders. Negative emotions, such as anxiety and fear caused by mortality salience, have been a globally neglected health problem (WHO, 2020). People should pay more attention to these negative impacts and take the necessary action to alleviate them. The quantified self is a good way to help better regain a sense of control. Through friendly and easy-to-use quantified self devices or applications, people can precisely self-track their exercise, health status, work performance, etc., and thus gain more control over various aspects of their lives. These devices can also help people develop better habits and promote well-being.

Second, these conclusions can also provide implications for businesses. Companies can promote their products by declaring that they can help consumers restore and enhance their sense of control and alleviate anxiety as a selling point. For instance, self-tracking devices for exercise and fitness can provide greater control over one's health and body, reducing concern about the usefulness of one's fitness plan.

Further, as the COVID-19 pandemic could last for several years and the number of infections and deaths continue to increase, people need to find more ways to help themselves adjust to the "new normal". Public health administrations should pay attention to people's conditions and encourage people to compensate for control loss in various healthy ways, such as quantified self behavior, keeping close to family and friends, and engaging in do-it-yourself projects, instead of engaging in

impulsive purchasing and materialism, and offer suggestions and professional guidance for the quantified self, such as health indicators and quantitative exercise references.

4.3. Limitations and future research

First, the participants in this study were all from China, but COVID-19 also threatens many other countries and regions. Future research should expand the survey sample to other countries to achieve more general conclusions. Second, in the past year, there has been a lot of research on mortality salience caused by COVID-19, but different researchers have different conclusions on the test of its stimulation and marketing effect, and some researchers fail to replicate mortality salience effect (Klein et al., 2019). This indicates that mortality salience effect may be affected by other potential factors, and it needs to be verified in more scenarios (for example, in areas outside of China, in the population infected with COVID-19, etc.) in order to enhance the robustness of the research conclusions. Moreover, cross-sectional data was used in this research, in future research, longitudinal data can be used to test the mediating effect. Third, as people widely use social networks, it is inevitable for individuals to compare or share their data with others. Sharing shifts quantified self behavior from an individual practice to a social practice (Harkin et al., 2016), thereby affecting individual's subsequent behaviors through intimacy with other community members. This also shortens the social distance between people. The possible behavioral changes and internal mechanisms of consumer participation in quantitative activities from the perspective of social network communities still lack in-depth discussions and verifications. Furthermore, in this paper, smart wearable devices and applications are used to measure the quantified self behavior, but for users with low technology acceptance (Rafique et al., 2020), digital devices and applications are likely to increase individual's anxiety. Further research needs to consider the influence of users' technology acceptance ability

and other factors. Last, individuals' behavior under the pandemic are affected by a lot of factors (Gtz et al., 2021). Further research can consider the moderating effect of factors such as government policy on the relationship between morality salience and quantified self behavior.

5. Conclusions

This study investigated the effects of mortality salience on quantified self behavior, as well as the corresponding underlying mechanisms. We found that mortality salience has a negative effect on perceived control, and a positive effect on quantified self behavior; perceived control mediates between mortality salience and the quantified self; and social distance plays a moderating role between mortality salience and perceived control. Specifically, when an individual's perceived social distance is more distant, mortality salience has a stronger negative effect on perceived control, which leads to more quantified self behavior. When perceived social distance is closer, mortality salience has a weaker negative effect on perceived control and leads to less quantified self behavior.

The COVID-19 pandemic has exerted an unparalleled influence on our lives, but necessary psychological help has not been available to all of us. It is of great significance to study how can we alleviate people's anxiety and fear of death.

CRedit authorship contribution statement

Yue Liu contributes to the theoretical building of the paper, wrote the original draft and takes responsible for paper submission.

Xingyang Lv Conceptualization, methodology, and made further reviewing and editing on the paper.

Ziyan Tang Data curation, collected the data and analysed the data.

All authors discussed the structure of the paper and finalized the manuscript.

Appendix 1

Variables	Items	Measurement items	Source
Mortality salience (MS)	MS1	When it comes to COVID-19, I am very much afraid to die	Templer (1970)
	MS2	When it comes to COVID-19, the thought of death often hits my mind	
	MS3	I feel nervous when thinking of the death scene caused by COVID-19	
	MS4	I feel terrified if I got quarantined and medical treatment because of COVID-19 infection	
	MS5	I am scared of COVID-19 infection	
	MS6	I am terrified of death caused by COVID-19	
	MS7 ^a	When it comes to COVID-19, the thought of death never bothers me.	
	MS8	When it comes to COVID-19, I constantly feel that time flies and time is short	
	MS9	When it comes to COVID-19, I fear dying a painful death	
	MS10	The topic of COVID-19 death makes me feel worried and resignation	
	MS11	I was afraid I do not have enough immunity to resist the Coronavirus effectively	
	MS12	When it comes to COVID-19, I often think of how fragile life is	
	MS13	I shudder at the thought of the heavy casualties of the COVID-19	
	MS14	I feel scared and sad when I saw the news about the numbers of deaths caused by the COVID-19	
	MS15	When it comes to COVID-19, I'm worried about the future	
Perceived control (PC)	PC1 ^a	During the COVID-19 pandemic, I feel helpless	Liu et al. (2016)
	PC2 ^a	During the COVID-19 pandemic, I feel powerless	
	PC3 ^a	During the COVID-19 pandemic, I feel like I don't have a sense of control	
Social distance (SD)	SD	Compared to the usual, during the pandemic, how frequently are you in contact with relatives, friends and colleagues? (including meetings, phone calls, chats or videos on various social media platforms)	Lev-On, Lissits (2016)
Quantified self product (QP)	QP1	Body fat scale or electronic scale	
	QP2	Smart band or smartwatch	
	QP3	Blood pressure or blood glucose monitor	
	QP4	Treadmill, rowing machine etc. With digital statistical display screen	
	QP5	Environmental monitoring equipment such as thermometer, hygrometer and formaldehyde tester	
	QP6	Other products with quantified self function	
	QP7	None	
Quantified self applications (QA)	QA1	Recording dietary calorie intake (such as Myfitness pal)	
	QA2	Remind of drinking water (such as waterminder)	
	QA3	Recording daily expenses, incomes (such as Next, Household account book)	
	QA4	Monitoring running mileage, speed (such as Adidas runtastic, Nike run club)	

(continued on next page)

(continued)

Variables	Items	Measurement items	Source
	QA5	Walking steps measurement (such as stepsapp)	
	QA6	Green energy by Alipay	
	QA7	Sleep monitoring (such as Pillow, autosleep)	
	QA8	Recording daily life, work, study and other arrangements (such as Timing, Life Cycle)	
	QA9	Recite words and read articles for English learning every day (such as Shanbay Word)	
	QA10	Health and physiological cycle (such as Clue, healthkit, Gyroscope)	
	QA11	Recording computer, mobile phone use time; monitoring work efficiency (such as RescueTime, Qobserve)	
	QA12	Weather forecast (temperature, humidity, PM2.5, UV index)	
	QA13	Other applications with quantified self function	
	QA14	None	

^a Stands for reverse item.

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