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During the last year, governments around the world used statistics data to keep people informed about Covid-19, to stress the importance of managing this disease and to encourage to adopt preventive behaviors. In this study, we investigated a mechanism underlying intentional non-precautionary behaviors during the COVID-19 lockdown. We hypothesized that the comprehension of COVID-19 risk statistics information had a central role in mediating the relationship between probabilistic reasoning ability and perceived statistics value (the antecedents) and the intention to act non-precautionary behaviors. Participants were 141 university students enrolled in an online study. Results revealed that probabilistic reasoning ability and perception of statistics value had a role in reducing the likelihood of engaging in transgressive behaviors through their impact on the ability to adequately reason with statistics data referred to the COVID-19 epidemic.

Keywords: Probabilistic reasoning, COVID-19 risk statistics information, statistic value, statistical literacy.

Introduction

The 2019 coronavirus disease (COVID-19) outbreak, caused by the novel coronavirus SARS-CoV-2, has become a global health threat, which has prompted the scientific community to question how to deal with it and mitigate its impact. It has been reported for the first time in Wuhan, Hubei Province (China) in late December 2019 and it has rapidly spread around all the five continents. As of 30 April 2020, the number of totals confirmed cases worldwide has exceeded 3 million (World Health Organization, 2020). On 20 February 2020, Italy identified its first case of local transmission and since March 20, Italy had surpassed China as the country with the highest amount of people who died from COVID-19 in the world (World Health Organization, WHO, 2020a). The number of deaths in Italy remained the highest worldwide until April 13, when the USA has become the nation with the highest number of deaths (WHO, 2020b). Even though governments around the world adopted different response strategies to tackle the pandemic, at some stage most countries either enforced or encouraged policies targeting preventive behaviors such as social distancing. However, these measures of containment have requested citizens a limitation of their activities and a modulation of their behaviors.

In medical decision-making, it has been widely demonstrated that adherence to health behaviors is influenced by risk comprehension related to the medical issue/problem. For example, risk comprehension has been found to influence risky decisions related to sexual behavior (Patel et al.,

2007), substance use (Lundborg & Lindgren, 2002) and tobacco consumption (Lundborg & Lindgren, 2004). In a systematic review about poor risk comprehension's health outcomes, it has been found that a lower comprehension of health information was associated with more hospitalizations, less mammography screening and influenza vaccination (Berkan et al., 2011).

Several studies about risk comprehension were then carried out to investigate what improves or hinders it. In this regard, as much of health-related information is expressed numerically (Reyna et al., 2009), a growing body of literature has sought to determine how health numeracy skills, the ability to understand and make use of health-related statistics (Låg et al., 2014), can improve people's risk comprehension. Health numeracy, intended as the ability related to probabilities, proportions, and percentages in the health domain, is low in the general population (Lipkus et al., 2001; Peters, 2012). However, it seems to have important impact on risk comprehension (Låg et al., 2014; Rolison et al., 2020).

Anyway, numeracy is a complex concept, encompassing several functional elements. Numeracy skills can be defined along a continuum that goes from elementary arithmetic skills to higher levels that encompass the ability to master probabilistic information and risk estimates (Reyna et al., 2009). Among these numerical skills, a growing interest has been recently posed on *probabilistic reasoning abilities* (Donati et al., 2014; Donovan et al., 2017; Hertwig et al., 2008; Primi et al., 2017). Probabilistic reasoning can be defined as the ability to think statistically about uncertain outcomes, and to make decisions based on probabilistic information. Probabilistic reasoning ability represents an important skill to correctly understand information related to risks. Interestingly, it has been highly documented that the majority of people have an inadequate comprehension of probabilities (Gigerenzer et al., 2005), even if they are highly educated (Lipkus et al., 2001). In the health domain, risk comprehension demands people to face uncertain outcomes and, therefore, with probabilities. For example, it has been demonstrated that the inadequate comprehension of risk and probabilities is critical in many areas, as the understanding of diagnostic tests (Gigerenzer et al., 2007) and drugs' side effects (Gigerenzer & Galesic, 2012). Specifically referring to COVID-19 related risks, it has been shown that when introductory statistic course students had higher probabilistic reasoning ability, they were more proficient in understanding COVID-19 risks (Primi et al., 2021). Additionally, probability reasoning ability, reflective ability and statistics interest had a role in reducing the likelihood of engaging in transgressive behaviors through their profitable impact on the ability to adequately reason with statistics data referred to the COVID-19 pandemic.

In line with this premise, we were interested in investigating the relation between probability reasoning ability and Covid Statistic Risk Comprehension in graduate students with more experience in statistics. We hypothesized that people who properly understand probability would be better in understanding and evaluating Covid Statistic Risk information. Additionally, as mass media communication about COVID-19 has been based on statistical concepts, such as "frequency", "shape of the curve", "flattening the curve", "positive rates", we hypothesized that a fundamental prerequisite to personally engage in data understanding would be the perception of the statistics value. It represents the usefulness, relevance, and worth of statistics in personal and professional life (Schau et al., 2003). Finally, as individuals who perceived risk related to COVID-19 as higher declared are

more likely to implement protective behaviors (de Bruin & Bennett, 2020, we included intentional non-precautionary behaviors during the COVID-19 lockdown as dependent variable.

In sum, our research question was to investigate the role of the probabilistic reasoning ability and the perceived value of statistics (positively related to each other) as antecedents of risk comprehension of COVID-19 statistics and this variable was hypothesized as the intermediary variable (mediator) between its antecedents and the dependent variable, that was conceptualized as intentional non-precautionary behaviors during the COVID-19 lockdown.

Method

Participants

Participants were 141 students attending graduate programs (60% female; mean age = 23.4; *SD* = 4.83) at the University of Florence (Italy). Introductory stats courses are compulsory in all the programs. For the pandemic all the programs were online. All students participated on a voluntary basis after they were given information about the general aim of the investigation. Participants completed an online survey on April 2020, during the first Italian lockdown.

Measures and Procedure

The *Probabilistic Reasoning Scale* (*PRS-B*; Primi et al., 2019) consists of 9 multiple-choice questions. The items include questions about simple, conditional and conjunct rule in probability, and the numerical data are presented in frequencies or percentages. A single composite score, based on the sum of correct responses, was calculated.

The *Value* subscale of the *Survey of Attitude towards Statistics* (*SATS-36*; Schau, 2003) is one of the subscales of the instrument measuring the six components of attitude toward statistics. The specific subscale consists of 9 Likert-type items using a 7-point scale ranging from *strongly disagree* to *strongly agree*. A single composite score was computed based on the sum of the responses, with higher ratings representing a higher perception of the Statistic Value.

The *Statistics Risk Comprehension Scale-Covid 19* (*SRCS-Covid 19*) was developed for the purpose of this study. In detail, we constructed a scale aimed at investigating people's understanding of the statistics about the epidemiological situation regarding the COVID-19 epidemic that was spreading in Italy in that specific historical period. Eight multiple-choice items with three response options (among which only one was the correct one) were created with the aim of covering the most debated issues in the Italian mass media concerning the COVID-19 at that time (e.g., cases of infections, dead cases out of infections, prevalence rates of positive COVID-19 tests). A single composite score, based on the sum of correct responses, was calculated. An example of item is: "*On 19 March 2020, in Italy there are about 40,000 infections and about 33,000 people who are still positive for the virus. This means that: a) As of that date, there are about 73,000 cases of infections; b) As of that date, there are about 7,000 cases between deceased and recovered; c) As of that date, there are about 7,000 cases of healed*".

In order to investigate the intention to act not precautionary behaviors put in place during the lockdown period, we developed a brief questionnaire through which participants were asked to

indicate whether they have intention to act the listed behaviors. Behaviors were defined as not precautionary on the basis of the restrictions imposed by Italian government through the Decree of President of the Council of Ministers (DPCM) issued on March 9, 2020 (https://www.gazzettaufficiale.it/eli/id/2020/03/09/20A01558/sg). An example of not precautionary behavior was "*Take a walk with some friends*". For each of the ten listed behaviors, participants had to respond "*no*" (scored as 0) if they had not the intention to engage in that behavior, or "*yes*" (scored as 1) if they had the intention to do that behavior, by specifically referring to the lockdown period. Among the listed behaviors, four were classified as not precautionary. In order to obtain a measure of intentional not precautionary behaviors, a total score was computed by summing responses given to the items investigating those kinds of behaviors.

After giving the informed consent, each scale was briefly introduced, and instructions for completion were given. All participants completed the *PRS-B, Value* subscale of the *SATS-36*, *SRCS-Covid 19* and the scale investigating intentional precautionary behaviors during the Covid 19 lockdown period. Time administration was about 30 min.

Results

To analyze the relationships between COVID19-related statistics risk comprehension and the scores relative to probabilistic reasoning ability, perception of statistics value, and intention to engage in not precautionary behaviors, correlations among the variables were calculated (Table 1).

	1.	2.	3.	4.
1. COVID19-related statistics risk comprehension	-			
2. Probabilistic reasoning ability	.46***	-		
3. Perception of statistics value	.33***	.36***	-	
4. Number of intentional not precautionary behaviors during the Covid 19 lockdown	-.22**	-.13	-.22*	-
M (*SD*)	5.09(1.52)	6.43(1.72)	46.71(8.36)	1.94(1.71)

*p<.05, **p<.01, ***p<.001

Table 1: Summary of intercorrelations, means, and standard deviations for scores of COVID19-related statistics risk comprehension, probabilistic reasoning ability, perception of statistics value, and intention to engage in not precautionary behaviors during the Covid 19 lockdown

As expected, the SRCS-Covid 19 score significantly and positively correlated with probabilistic reasoning ability and perception of statistics value. It was also significantly and negatively correlated with the number of not precautionary behaviors that are likely to take be placed. Moreover,

probabilistic reasoning ability and perception of statistics value were positively inter-related, and the number of intentional not precautionary behaviors were significantly and negatively correlated with both probabilistic reasoning ability and perception of statistics value.

In order to investigate our hypothesis on the mechanisms underlying the relationships among these variables, we conducted a path analysis employing the maximum likelihood (ML) method using AMOS 16 software (Arbuckle, 2007). The model included probabilistic reasoning ability and perception of statistics value as COVID-19 statistics risk comprehension's antecedents (positively related to each other). In turn, statistics risk comprehension was hypothesized as the intermediary variable (mediator) between the antecedents and the dependent variable, that was conceptualized as the number of intentional not precautionary behaviors during the Covid 19 lockdown.

The presence of the mediated effect was investigated through the test of indirect effects (Cheung & Lau, 2008). In AMOS the Bootstrap confidence interval method is used to define the confidence intervals for indirect effects (MacKinnon et al., 2004). In mediation analysis, bootstrapping is used to generate an empirically derived representation of the sampling distribution of the indirect effect, and this empirical representation is used for the construction of a confidence interval for the indirect effect. The 90% bias-corrected confidence interval percentile method was implemented, using 2,000 bootstrap samples. Confidence intervals for the indirect effects which do not contain 0 are considered as indicative of significant indirect effects, thus meaning the presence of a mediated effect. Several goodness-of-fit indices were used to test the adequacy of the model: Comparative Fit Index (CFI) (Bentler, 1990), the Tucker-Lewis Index (TLI) (Tucker & Lewis, 1973) and the Root Mean Square Error of Approximation (RMSEA) (Steiger & Ling, 1980). CFI and TLI values equal to .90 or greater and RMSEA values of .08 or below are considered as indices of adequate fit. The model showed a good fit to the data (CFI = .976, TLI = .927, RMSEA = .074). All coefficients were statistically significant in the expected directions. Specifically, results revealed that probabilistic reasoning ability and perception of statistics value – positively inter-correlated – had a significant direct and positive effect on COVID-19 statistics risk comprehension. In turn, COVID-19 statistics risk comprehension was directly and negatively related to the number of intentional not precautionary behaviors during the Covid 19 lockdown. Results also showed significant and negative indirect effects from the independent variables on the number of intentional not precautionary behaviors during the Covid 19 lockdown, indicating that probabilistic reasoning ability and perception of statistics value had a role in reducing the likelihood of engaging in transgressive behaviors through their profitable impact on the ability to adequately reason with statistics data referred to the COVID-19 epidemic (Figure 1).
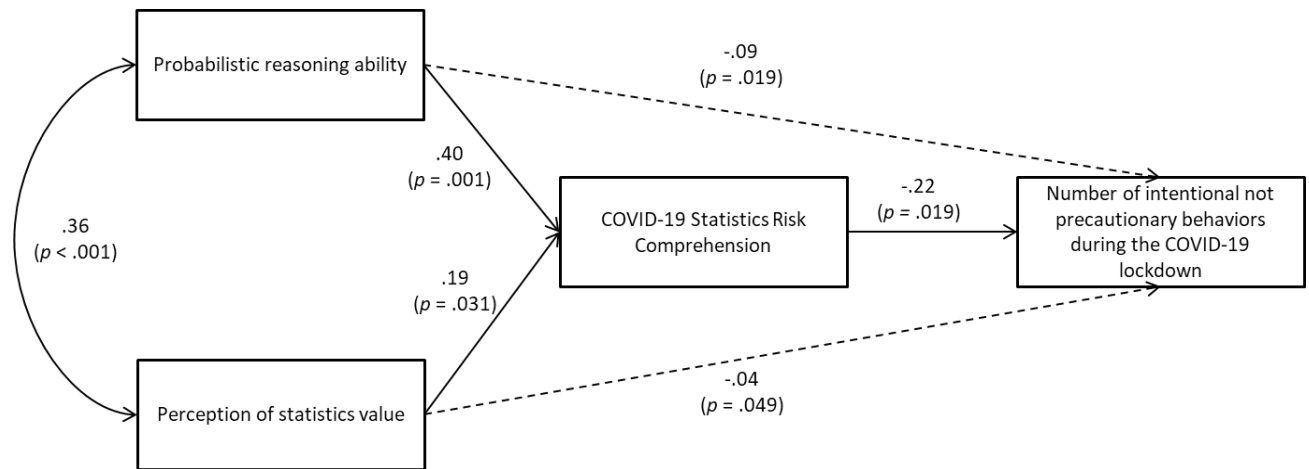
Figure 1: Path model among the variables. Straight lines indicate direct effects. Dotted lines indicate indirect effects. All the coefficients are standardized

Conclusion

The emergency caused by coronavirus disease 2019 (COVID-19) has led to a surge in interest in trustworthy statistics and a greater number of people accessing statistical information about their own communities. Results showed the role of mediator of the statistics risk comprehension confirming the need to have a deep understanding of statistics, especially in the context of a global pandemic such as Covid-19. We found that probabilistic reasoning ability and perception of value in statistic had indirect effects on the intention to act non-precautionary behaviors through statistic risk comprehension. This result is in line with other studies concerning diverse health contexts, that showed that numeracy (in its different components) has consistently been related to risk perception, more accurate understanding of risks, and better decisions (Garcia-Retamero et al., 2019), and with explanation models related to behavioral conducted in the pandemic (Primi et al., 2021). More generally, our findings show the importance of statistical literacy as an essential skill for all citizens, especially in the context of a global pandemic such as Covid-19.

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