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A global survey on the associations between the lockdown group, free memory recall and emotional responses during the COVID-19 lockdown

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The unprecedented outbreak of the COVID-19 pandemic has altered the course of many lives, resulting in multiple health and social challenges. Due to the speed at which this pandemic spread, various public health 'lockdown' measures were introduced to mitigate its spread. The outcome of adherence to these measures has revealed the possible influence on individuals' varying cognitive abilities. Accordingly, this study aimed to explore the predictive relationships between lockdown responses and COVID-19 restrictions, memory recall performance, and associated emotional responses while examining the sociodemographic influences of age and sex. Participants were drawn from a secondary dataset of an international online survey study of 1634 individuals aged 18–75 years across 49 countries. Participants' demographic questionnaires, free memory recall, and hospital anxiety and depression scale scores were used to collect the data for analysis. Four-way MANOVA and hierarchical multiple regression were utilised to explore the mean differences and predict relationships between the study variables. Significant differences were found in memory recall performance and anxiety and depression scores across lockdown groups (the comply, sufferer, and defiant). Regression analysis indicated that age and gender were predictive markers of lockdown responses and anxiety ($R^2 = 0.14$, $F_{4,1625} = 66.15$, $p < .001$, $f^2 = 0.17$), while age was the only predictor of lockdown responses and depression association ($b = -0.78$, $t(1625) = -4.35$, $p < .001$). Lockdown compliance was associated with better free recall ($M = 8.51$, $SD = 6.38$, $p < .001$; $\eta^2 = 0.01$), lockdown suffering was associated with greater anxiety ($M = 9.97$, $SD = 4.36$, $p < .001$; $\eta^2 = 0.06$), and lockdown deviance was associated with greater depression ($M = 7.90$, $SD = 3.12$, $p < .001$; $\eta^2 = 0.05$). The current study provides valuable information on the mechanisms of cognitive interpretations and emotional arousal in individuals' social isolation responses to recent life stress and potential severe pandemics. This may support the need for robust interventions aimed at improving people's psychological appraisals associated with anxiety in preparation for any new potential waves or future pandemics.

Keywords COVID-19 lockdown, Free memory recall, Anxiety, Depression, Public health measures

The growing threat of global pandemics has set the stage to further explore the role of sociobehavioural responses to public health compliances that are put in place to reduce the spread and contain such adverse and uncertain events[1]. The novel approach of collective social adherence to various social rules (e.g., country-level lockdown) has been identified as the most effective approach for mitigating the social problems associated with uncertain

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and threat-imposed global pandemics[2,3]. The outbreak of COVID-19 and its spread at an unprecedented speed necessitated imposed health measures to reduce the high morbidity and mortality rates. Different social adherence and preventative measures, such as social distancing, wearing masks, and hand washing, were geared toward reducing person-to-person transmission, with estimated higher compliance required to control the outbreak and reduce viral spread[4]. However, the effectiveness of these measures, which were initiated before widespread vaccine rollout, largely depended on individual responses and societal adherence to the imposed COVID-19 lockdown restrictions[5,6]. While the dynamics surrounding social adherence to pandemic rules are yet unknown, understanding social isolation measures has proven to be a valuable tool for mitigating disease spread and promoting sociobehavioural attitudes consistent with public health measures. During any viral infection, such as during the COVID-19 pandemic, the psychological reactions of the population, including social disorders and the prevalence of psychosocial diseases such as anxiety and depression, play an important role in disease spread[7].

The mental health outcomes of viral infections, such as the COVID-19 pandemic and the resulting strict lockdown measures, have resulted in negative impacts on the emotional and psychological health and well-being of individuals and communities that were directly and indirectly affected by the pandemic[8]. Consequently, because of limited access to mental and medical health resources, as well as inefficient primary healthcare infrastructure, especially in sub-Saharan Africa, there has been a high prevalence of anxiety and depressive symptoms. This spread was exacerbated by the COVID-19 pandemic and by prolonged stringent measures applied by public health institutions to mitigate this highly contagious pandemic[8,9].

Studies have shown the prevalence of psychological distress, specifically anxiety and depression[10,11], during prolonged COVID-19 lockdowns. These restrictions were associated with social adherence measures such as reduced social interaction, specifically stringent social distancing and systematic quarantine. The consequence of such social adherence to lockdown rules has led to devastating mental health outcomes, including emotional distress, thereby exposing people to psychological risks and heightened levels of anxiety and depressive symptoms[12]. These outcomes have influenced individual and group social engagement and behavioural responses to the pandemic and its strict containment measures[13,14]. In addition, peoples' behavioural responses to lockdown measures clearly suggest the possibility of stratifying them according to the classification of their behaviours[15].

Furthermore, studies have suggested that the association between increased mental health symptoms (e.g., anxiety and stress) tends to modulate the encoding, consolidation, and retrieval of episodic memory processes[16–19]. The consensus that emotional episodic events are better remembered than neutral events further reinforces the significant influence of emotion in improving the encoding and consolidation of memory processes[20,21]. Previous studies have shown that emotional memory recall is better than neutral recall, especially for emotional memories with negative valences[22,23]. In light of this, research has shown that threatening events such as the COVID-19 pandemic and resulting lockdown measures may significantly modify memory recall in individual and group lockdown responses[1]. Additionally, widespread COVID-19 and extended quarantine days have been shown to influence populations' emotional responses, such as fear of contagion and mortality, resulting in heightened stress, anxiety and depression[24]. As such, the relationship between emotional responses and episodic memory recall could be a contributor to anxiety and depressive symptoms among individuals of varying age groups and with different gender structures during the COVID-19 pandemic restrictions[25].

Episodic memory is a system involved in conscious awareness and recollection of events and personal experiences[26]. Literature has posited that varying behavioural outcomes and responses to COVID-19 lockdown measures may potentially influence an individual or group's cognitive abilities, such as episodic memory recall[1,27]. Despite this, there is still a dearth of research on how pre-existing memory processes and profiles are influenced by individual and group responses to uncertain pandemics such as COVID-19 and its various social isolation measures. This phenomenon is especially prevalent globally, where limited studies have investigated how cognitive abilities, such as episodic memory recall, anxiety, and depression, are associated with varying responses to COVID-19 lockdown measures.

The outcomes of recently recognised psychological responses to COVID-19 lockdown measures have shown that behavioural changes in individuals' compliance levels to pandemic social restrictions are influenced by prevailing social stereotypes and cultural norms[15,28]. For example, a UK study showed that people commonly accepted lockdown rules (48%), followed by experiencing suffering (44%), and the least common group resisted the UK lockdown rules (9%). However, these responses could also influence people's ability to correctly appraise their self-regulation strategies. These strategies could be linked to decision-making processes within the cognitive structures of individuals' executive functioning capacity in terms of levels of cognitive flexibility and working memory capacity[27,29]. As elucidated by Del Missier et al.[26] , associations between memory and decision-making are evident when emotion-based judgments are executed under higher or lower cognitive loads. The operationalisation of this association highlighted the assumption that semantic response (a type of memory response that consists of factual information and meaningful knowledge properties) plays a fundamental role in background knowledge decision-making processes, while past experiences involve influences of episodic memory (a memory system involved in conscious awareness and recollection of events and personal experiences)[26]. This means that an association between memory and decision-making processes may influence the outcome of individual psychological or behavioural responses arising from new semantic frameworks and episodic content retrieval that are linked to social isolation during COVID-19 lockdown measures[30,31].

While various cross-sectional and reviewed studies[27,32] have focused on the psychological well-being and cognitive performance of individuals during the COVID-19 pandemic, we could not locate any study that specifically investigated the association between memory recall processes and social adherence during the lockdown period, especially within the broader global survey study. Our study aimed to investigate the associations between lockdown group responses to COVID-19 restrictions and free memory recall and between

associated anxiety and depression levels in participants drawn from 49 different countries across the globe. Additionally, the study further explored the predictive effect of age and gender on the relationships between these constructs. Research has shown the effects of age and gender differences on auditory and visual episodic memory performance among younger and older adults[33,34]. While contributing to the body of knowledge, our study predicted that there would be significant differences across lockdown group responses (comply, sufferer, defiant) on free memory recall and associated emotional responses related to anxiety and depression. Furthermore, we hypothesised that age and gender would predict the associations between COVID-19 lockdown group responses and free memory recall, and between anxiety and depression.

There are some theories that propose the inter-relationship between executive functions and emotions. For example, the revised Multicomponent Model of Baddeley[35] elaborates on the hypothesis of the relational influence between the executive function structure of working memory and the construct of emotion. This model provides an understanding of the interplay between human reasoning and decision-making, in which emotions, such as *fear*, *anxiety*, *and depression*, play an integral part[36,37]. The model also accounts for influences between emotions and memory, and establishes an assumption that human cognition, including memory, is affected and/or modulated by emotion[38,39]. Furthermore, to ascertain the distinctiveness of emotion's characteristics and influence within the cognitive structure of memory storage components[40,41], the *semantic activation model*[42,43] posits high interrelatedness of emotional words, which enhances its better recall process than other abstract or neutral words. For instance, this model explains why emotional words are more image-represented than abstract words (although less represented than concrete words) because of their semantic relatedness, thereby making it possible to influence attentional processes and episodic memory capacity[44].

Results

Effect of lockdown group response on memory recall and associated emotional profiles

As hypothesised, we found significant differences (ranging from small to medium effect sizes) in the lockdown group responses on free memory recall ($F_{2,1594}$ = 6.67, $p < .001$, $\eta^2 = 0.01$), anxiety ($F_{2,1594} = 53.27$, $p < .001$, $\eta^2 = 0.06$), and depression ($F_{2,1594} = 41.64$, $p < .001$, $\eta^2 = 0.05$). The significant associations were weak across the results, particularly in the case of free memory recall, which had the weakest effect size. As shown in Table 1, in particular, our sample perceived significantly better memory recall in the comply group ($M = 8.51$, $SD = 6.38$) than in the sufferer ($M = 7.83$, $SD = 6.11$) and defiant ($M = 5.69$, $SD = 6.69$) groups. Examining the changes in the emotional profiles of the participants in the lockdown group, we found significantly greater anxiety levels in the sufferer group ($M = 9.97$, $SD = 4.36$) than in the defiant ($M = 9.78$, $SD = 3.22$) and comply ($M = 7.29$, $SD = 4.02$) groups. Furthermore, a significantly greater level of depression was recorded in the defiant group ($M = 7.90$, $SD = 3.12$) than in the sufferer ($M = 7.41$, $SD = 3.80$) and comply ($M = 5.62$, $SD = 3.61$) groups.

Relationships between sociodemographic factors, free memory recall, anxiety, and depression

The full regression model of lockdown group responses and the sociodemographic variables age and gender significantly predicted free memory recall ($F_{4,1625}$ = 9.15, $p < .001$). When sociodemographic variables were introduced into the model (adjusted $R^2 = 0.020$, $F(4, 1623) = 0.99$, $p = .371$), the adjusted R^2 values were minimal, indicating that only 2% of the variance in memory recall was explained by the predictors. The associated F-statistic for the predictors added was non-significant, suggesting that including age and gender did not improve the model's ability to explain variance in memory recall over what was accounted for by the lockdown group alone. Furthermore, only the lockdown group variables, sufferer group (b = -0.75, $t(1623)$ = -2.18, $p = .030$) and defiant group (b = -2.71, $t(1623)$ = -5.69, $p < .001$), were significantly different, as shown in Table 2. These results suggest that although the full model was significant, sociodemographic variables were not significant predictors of the relationship between lockdown group response and free memory recall in this study.

Furthermore, as reported in Table 2, age and gender were shown to predict the relationship between the lockdown group and anxiety. The hierarchical regression showed a statistically significant model at both steps of

Dependent variable	Lockdown group comparison		Mean difference	Sig.	95% Confidence interval	
	I	J			LB	UB
Free memory recall	Comply	Sufferer	0.59	0.127	−0.168	1.347
	Comply	Defiant	2.652**	0.000	1.203	4.101
	Sufferer	Defiant	2.062*	0.006	0.598	3.527
Anxiety	Sufferer	Comply	2.434**	0.000	1.959	2.909
	Defiant	Comply	2.184**	0.000	1.276	3.093
	Sufferer	Defiant	0.249	0.594	−0.669	1.167
Depression	Sufferer	Comply	1.872**	0.000	1.436	2.308
	Defiant	Comply	2.314**	0.000	1.480	3.147
	Defiant	Sufferer	0.442	0.304	−0.401	1.284

Table 1. Differences in memory recall and emotional profiles between lockdown groups. $N = 1630$. *Sig.* significance. ** = $p < .001$. * = $p < .05$.

Variable	Free memory recall			Anxiety			Depression		
	b	95% CI	*β*	*b*	95% CI	*β*	*b*	95% CI	*β*
Intercept	8.79**	[8.13, 9.44]		8.78**	[8.36, 9.19]		6.06**	[5.68, 6.43]	
COVID-19 lockdown group (ref. comply group)									
Sufferer group	0.75*	[−1.42, −0.07]	−0.06	2.48**	[2.06, 2.90]	0.28	1.82**	[−1.43, 2.20]	0.24
Defiant group	−2.71**	[−3.64, −1.77]	−0.15	2.72**	[−3.64, −1.77]	0.22	2.31**	[1.77, 2.84]	0.21
Sociodemographic variables									
Age	−0.13	[−0.74, 0.49]	−0.01	−1.25**	[−1.64, −0.87]	−0.15	−0.78**	[−1.13, −0.43]	−0.10
Gender	−0.45	[−1.08, 0.18]	−0.04	−1.52**	[−1.92, −1.13]	−0.18	−0.13	[−0.49, 0.23]	−0.02
Regression statistically significant results									
F(4, 1625)	9.15**			66.15**			34.85**		
t value	**26.20****			**41.75****			**31.54****		
Change in R^2	**0.001**			**0.03**			**0.01**		
R^2	**0.02**			**0.14**			**0.08**		

Table 2. Results of the regression model predicting the lockdown group and emotional profiles. $N = 1630$. b = unstandardised regression coefficient; β = standardised regression coefficient; *CI* confidence interval. $^{**}p < 0.001$. $^{*}p < 0.05$. Significant values are in bold.

the model analysis. The results showed a total variance of 13.8%, explained by the full model ($R^2 = 0.14$, $F_{4,1625} = 66.15$, $p < .001$, $f^2 = 0.17$). When controlling for lockdown group response in the full model, both age (b = -1.25, $t(1625)$ = -6.36, $p < .001$) and gender (b = -1.52, $t(1625)$ = -7.55, $p < .001$) had statistically significant effects on anxiety. The results regarding the effect of age on the association between the lockdown group and anxiety, therefore, suggest that younger adults appear to be more anxious in their response levels during COVID-19 lockdown measures than older adults are. Similarly, the regression results further showed that females had greater anxiety in their lockdown response levels than males did.

The full model of the lockdown group, age and gender in predicting depression also showed a statistically significant result ($R^2 = 0.080$, $F_{4,1625} = 34.85$, $p < .001$, $f^2 = 0.09$). These results suggested that sociodemographic factors predict the association between lockdown group response and depression. However, while investigating the variable(s) that contributed to this significant prediction when controlling for the lockdown group in the analysis, age was the only significant predictor (b = -0.78, $t(1625)$ = -4.35, $p < .001$), and gender was a nonsignificant predictor (b = -0.13, $t(1625)$ = -0.69, $p = .490$). This result, therefore, suggested that younger adults in this study were more likely to be depressed than older adults were, as shown in Table 2.

Due to the exploratory nature of this study and varying sample sizes across countries, further analysis was conducted to support the results, focusing on countries and regions with larger samples. A similar pattern of results emerged from most analyses, although many of the analyses were non-significant, particularly from countries and groupings with smaller sample sizes. For instance, the regression analysis of participants from the United Kingdom on lockdown group responses and the sociodemographic variables of age and gender non-significantly predicted free memory recall ($F_{4,376} = 1.51$, $p = .198$). However, the same model was significant when combining UK, Poland and Portugal sample groupings ($F_{4,898} = 7.01$, $p < .001$). Details of the results analysis are shown in the supplementary results section.

Discussion

Our findings revealed significant associations between free memory recall, anxiety, and depression across lockdown group response levels. Individuals in the compliant group had better free recall, those in the sufferers group had significantly greater anxiety, and those in the defiant group had greater depression symptoms during the 2020 period of the global COVID-19 lockdown. Age and gender were also significant predictors of anxiety in the lockdown group. Another important finding was that none of the sociodemographic variables, specifically age and gender, were significant predictors of lockdown group responses and free memory recall relationship. The rationale of this study was to provide insight into the mechanisms of semantic coding associated with free recall memory and how these mechanisms influence varying individual and group compliance responses to pandemic lockdown restriction measures. Additionally, the study showed the intriguing influence of emotional content on the neural processes of individuals and the group's psychological outlook on social isolation measures.

The significant association between lockdown group responses and free memory recall showed that the comply group exhibited better memory recall than the sufferer and defiant groups. This was consistent with our hypothesis that those with poorer memory recall (the sufferer and defiant groups in this study) tend to suffer from poorer emotion self-regulation and flexible updating[39,45]. This outcome would lead to our second hypothesis that this group would report significantly greater negative emotional responses to social isolation rules, which often required flexible thinking to cope during the COVID-19 pandemic. Furthermore, the overall memory recall performance of the individuals in the comply group (those who easily adhered to group/social norms and COVID-19 lockdown rules) indicated a positive recency effect on their delayed recall tasks. This effect tapped into a more stable long-term storage mechanism component of the free recall performance, which is mainly affected by semantic coding[46,47]. The storage mechanism component is unaffected by the rehearsal-preventing task of delayed recall; as such, correctly recalling texts from the beginning of the passage was more prevalent in

the long-term storage component than the short-term storage mechanism of single-trial free recall, which also reflects a recency effect but with immediate recall of the recently rehearsed texts from the end of the passage. It must be noted, however, that, based on the nature of the online survey used in this study, the assumption was that participants engaged the recency effect of delayed recall with distinctively long pauses (between 20 and 30 seconds) that preceded their recall response – a unique response time associated with free recall memory tasks[48]. In light of this, interpretation of this finding was considered in the context of this observation.

The significant findings across the lockdown group could be attributed to cognitive interpretations of individual/group variations as an indication of significant free memory recall performance findings[17,49]. In light of these cognitive variations, it was not unexpected that free memory recall performance between the comply and sufferer groups indicated non-significant differences in memory recall. However, performance significantly differed between the comply and defiant groups and between the sufferer and defiant groups. Another possible reason for this can be attributed to the impact of recent life stress[18] (such as the COVID-19 pandemic) on the cognitive process of the participants. The outcome of this stress, reflected as either acute or chronic, was assumed to impair the retrieval process within the memory recall capacity. As a result, the recall process impinges upon individual episodic memory content, which happens to be the seat of the long-term storage mechanism of the free memory recall task[50]. This finding indicates that recent life stress, which might be more pronounced in the suffering and defiant groups than in the compliant group in our study, has the potential to limit the capacity of long-term storage mechanisms, especially when individuals or groups are faced with life-threatening psychological and emotional challenges. The COVID-19 pandemic could presumably exert substantial effects on the memory retention and retrieval abilities of individuals with cognitive variations necessary for decision-making responses[51].

Age-related decreases in cognitive function could also be attributed to the significant effect of these outcomes. The participants' sample distribution across different age cohorts showed a positively skewed distribution of their free memory recall scores. Therefore, it was not unusual to expect significant age differences to be associated with the memory recall performance of respondents across lockdown groups in this study. This was prevalent with reference to reduced inefficient recall and retrieval performance of the episodic content of the long-term memory store[52]. Although evidence-based results have lent support to this assumption[53,54], the experimental studies of Craik[55] and Raymond[56] foreground the assumption that the effectiveness of memory recall from long-term storage of episodic memory is affected by successive age-related increases, including the length and stimulus size of the recalled vocabulary or text[57]. This finding suggested that there may be certain differential and ineffective cognitive functioning processing in older adults compared to younger adults. This was due to poor retrieval and selective decline in performance from the long-term storage mechanism of episodic memory[58].

This study also revealed important significant findings on anxiety and depression across lockdown groups. The results showed that the sufferer group experienced greater anxiety symptoms than the defiant and comply groups. In comparison, the defiant group displayed greater depressive symptoms compared to the sufferer and comply groups. These findings suggested that both anxiety and depressive symptoms were significantly associated across the lockdown group responses. These findings are consistent with previous literature and systematic reviews, especially on COVID-19 behavioural and cognitive responses to social isolation measures[10,27,28]. While depressive symptoms decreased across the lockdown response levels compared to heightened anxiety levels, the effect sizes of both anxiety ($\eta^2 = 0.63$) and depression ($\eta^2 = 0.50$) across group responses were relatively modest. Nevertheless, the significant differences in emotional responses across the lockdown groups could be due to several reasons. First, the global lockdown disrupted people's personal, financial, and social lives, resulting in a negative psychological outlook. Moreover, the extended 'sit-at-home' lockdown restrictions might have elevated individual anxiety and depressive responses. This might have been more prevalent in the sufferer group because of their assumed financial difficulty and low optimism during the pandemic lockdown. This might further aggravate their anxiety levels because of agitation and lower optimism in the government's response to controlling disease spread.

This explanation is consistent with recent literature on the exacerbated emotional levels of anxiety, stress, and depressive symptoms in people during the COVID-19 pandemic, which has resulted in maladaptive coping responses across individuals and group outcomes[49,59]. Additionally, the role of misinformation due to high social media exposure and usage, including emerging conspiracy theories on COVID-19 infections and treatments[60,61], could also be attributed to significant differences in emotional content across lockdown groups. Frequent social media usage and lack of government plans to respond adequately to changing scientific information (leading to misinformation) might have negatively influenced people's emotional state toward inappropriate responses to pandemic lockdown measures. For instance, the defiant group, which was susceptible to high social media exposure and usage, was linked to greater depressive symptoms in our study. This finding is consistent with recent studies that postulated the significant association of increasing misinformation, conspiracy theories, and fake news on COVID-19 infections and outcomes with heightened emotional and psychological responses[62,63]. In light of the reviewed literature and hypothesis that stated that significant differences exist between lockdown group responses to COVID-19 social restriction measures on participants' emotional content of anxiety and depression, the findings of this study therefore offer consistent support for the body of knowledge in favour of the significant effects of these measures on emotional responses to COVID-19 lockdown measures.

Consistent with the findings of recent studies[29,64], our regression analyses showed that age significantly predicted the associations between lockdown group responses and emotional responses to anxiety and depression. The negative prediction of the result suggested that younger adults were more exposed to heightened levels of anxiety and depression than older adults were. An explanation for this could be that older individuals have the emotional capacity or greater memories of overcoming past difficulties, to contextualise a stressor, such as the outcome of the COVID-19 lockdown measures, which helps them maintain a more stable emotional balance than younger individuals[65]. Additionally, older adults tend to have a more mature social disposition and

better financial support base, such as better-paying jobs, which might reduce the context of emotional imbalance than younger adults. Furthermore, gender significantly predicted group responses and anxiety relationships. Compared to males, females showed higher anxiety symptoms, which was consistent with the findings of previous studies indicating a significant increase in anxiety observed in females[66,67]. A potential explanation for this could be because of the assumptions that females bear more disproportionate domestic and caregiving responsibilities than men, especially during the pandemic period, such as during the COVID-19 social isolation, which results in contextually skewed gender divisions of labour in society, including household settings[68,69]. As a result, females could be considered more susceptible to increased anxiety and depressive symptoms. Social isolation measures such as restricted physical mobility during the pandemic could also increase females' exposure to domestic violence and hostile experiences. This could exacerbate their emotional disturbance levels, especially in areas where gender violence practices and narratives are prevalent, such as sub-Saharan Africa, including Southern Africa[70–72].

Materials and methods

Participants

This study was nested within an existing dataset of a larger international online survey study conducted between July and September 2020. The sample consisted of participants from 49 countries in Africa, Asia, Europe, North America, and South America, as shown in Fig. 1. A larger study utilised non-probability, convenience, and snowball sampling methods. No restrictions were imposed on referring friends or family members, as participation was voluntary. Brief information about the aims of this study was provided online to all participants. All methods were performed in accordance with the relevant guidelines and regulations.

Given the circumstances of the COVID-19 pandemic at the time of the study, global online advertisement emerged as the most suitable non-probability sampling method. This approach effectively mitigated the risk of infection associated with face-to-face recruitment and ensured adherence to lockdown regulations and stringent social distancing protocols[73,74]. The Prolific software was used to recruit participants and collect their data for this study. It is an efficient online survey platform suitable for recruiting participants for social science and psychological research purposes[75]. It is considered an ethically sound research tool that prioritises the treatment of participants within any of its research subject pools and has a user-friendly interface with other data analysis software such as Qualtrics[76]. Ethical approval for this study was obtained from the Liverpool John Moore University Ethics Committee (approval code 20/NSP/035) and the University of the Witwatersrand Health Research Ethics Committee (non-medical; approval code MASPR/21/08). Written Informed consent was obtained online from all participants before data collection. Furthermore, participants were eligible if they were adults aged 18–75 years, had no psychological conditions as declared by each participant, and could speak and write in English. Among the total valid sample size of 2309 participants, 1634 respondents were classified as eligible. Participants were excluded due to incomplete online surveys ($n=613$), missing data on age ($n=29$), insufficient data on non-binary sex ($n=18$), or missing education ($n=15$). A detailed list of participating countries is included in the supplementary section of this paper.

Sociodemographic and lockdown response characteristics

The demographic characteristics of the sample ($N=1634$) are summarised in Table 3. The participants' ages ranged from 18 to 74 years ($M=28.60$, $SD=10.92$). There were slightly younger adult participants (50.6%) than older adults (49.4%). Most participants self-identified as male (54.30%), were from Europe (80.20%), and fell

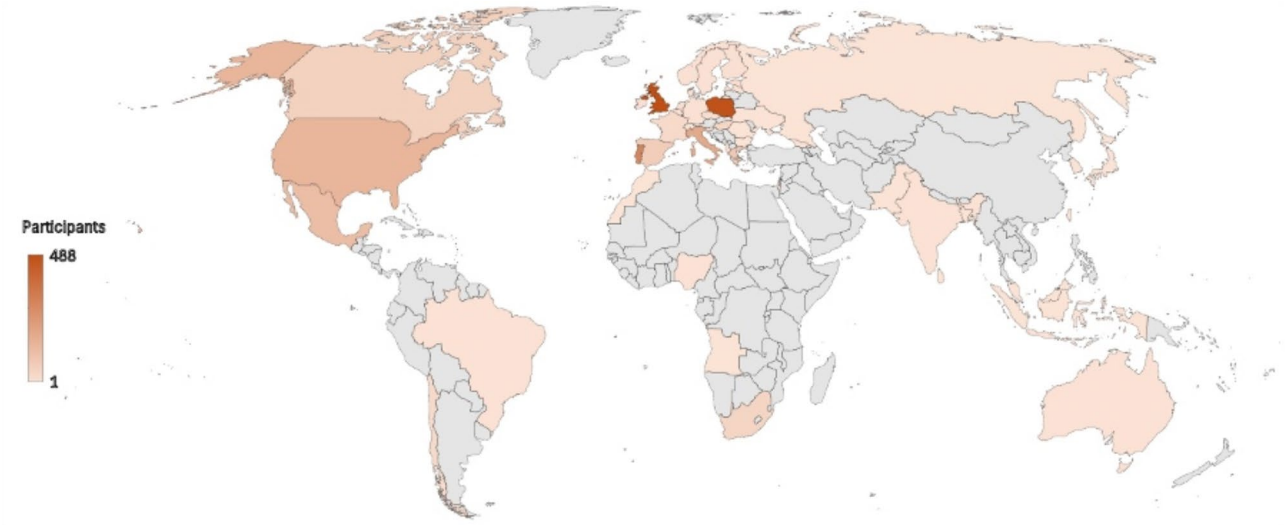

Fig. 1. Map of the 49 participating countries with total sample size. ($N=2309$). We did not obtain samples from countries in grey.

Demographic variables		Group	*n*	%
Age	*M(SD)*: 28.60(10.92)			
	Range: 18–25	Younger adults	827	50.60
	Range: 26–74	Older adults	807	49.40
Gender		Female	747	45.70
		Male	887	54.30
Continental grouping		Europe	1308	80.20
		North America	155	9.50
		South America & the Caribbean	109	6.68
		Africa & Middle East	46	2.82
		Asia & Australasia	13	0.80
Lockdown group		Comply group	800	48.96
		Sufferer group	607	37.15
		Defiant group	227	13.89

Table 3. Sociodemographic characteristics and COVID-19 lockdown group distribution. Total $N = 1634$ for all variables except for continental grouping ($N = 1631$); *M* mean; *SD* standard deviation.

within the comply lockdown grouping (48.96%). The comply group had the most participants ($n = 800$), followed by the sufferer group ($n = 600$), while the defiant group ($n = 227$) had the lowest participant grouping.

Instruments

Demographic and COVID-19 experience questionnaire

The survey used self-reporting questionnaires consisting of two sections. In the first section, participants' sociodemographic data, specifically age range and sex (binary classification), were collected. Participants' sex classification was self-reported by each of the participants. The second section utilised the 54-item COVID-19 experience questionnaire created by the authors, which was based on a previous study that identified 3 lockdown response groups in the UK from King's College, London[15]. The questionnaire (available on request) was used to assess lockdown responses in this cohort. The questionnaire was answered on a 5-point Likert scale, and assessed participants' beliefs, attitudes, and behaviours around COVID-19 pandemic characteristics and government-imposed lockdown measures[49]. Accordingly, three lockdown groups were categorised based on the *K-means* cluster analysis of the questionnaire scores (see below), namely: (1) the Comply group (CG): people with higher adherence to group/society norms and stereotypes; (2) the Sufferer Group (SG): those who adhered to lockdown rules with some deviations and were known to possess conflicting outlooks on social norms; and (3) the Defiant Group (DG): those with a negative outlook on COVID-19 lockdown restrictions and low adherence. This classification aligned with the three groups identified by another study[15].

Memory recall

An online self-administered memory test was measured by a free memory recall test (FMRT), which is adapted for online administration. The adapted FMRT assessed memory recall of previously memorised statements of unrelated or coupled textual words that contained concreteness, emotionality, and neutrality[77,78]. The FMRT consists of 30 bold selected words (e.g., viral, swarming, quack) within the passage; these words are made available to participants to recall by writing as many bold letters as they remember after an overt rehearsal of the passage after 20–30 s. The bold text to be recalled represents categories of concrete (e.g., door), abstract (e.g., silence), neutral (e.g., ordinary), and emotional (e.g., viral) words to test participants' memory recall performance. The bold text recall did not have to follow the sequence as it appeared in the passage. Since it was an online assessment, the bold text recalled was to be written down in the provided online space. Additionally, spelling errors were not accounted for, but synonyms were not recorded as the correct answer to the bold text. Participants were not given specific time to recall the bold text, but it was assumed that the recall would be quicker since it was part of an online data collection activity. The FRMT scores ranged from 0 to 30, with each correctly recalled word given one point. The FRMT has a strong internal consistency reliability of .71[78].

Anxiety and depression

The presence of anxiety and depression was measured by the Hospital Anxiety and Depression Scale (HADS)[79]. It is a brief self-assessment emotion questionnaire designed to assess symptoms of anxiety and depression within non-psychiatric hospital settings[80]. It comprises two subscales for anxiety and depression, each having seven items (closed format) of a 4-point Likert scale (0–3), with a range of 0–21 for each subscale[81]. A higher total score indicates a greater severity of anxiety and/or depression. Scores ranging from 0 to 7 are in the normal range; 8–10 as mild or borderline; 11–14 as moderate; and 15–21 as severe self-reports of anxiety and/or depression[82]. The HADS subscales are considered a justifiable measure of severity, with reliability measures ranging from 0.83 to 0.93 for anxiety and from 0.74 to 0.90 for depression[80,83]. The Cronbach's reliability coefficient for the HADS in this study was 0.80 for anxiety and 0.74 for depression.

Data analyses

K-means cluster analysis

The creation of a lockdown response variable in this study was adopted in line with the online survey study through a *k*-means cluster analysis. The larger international online study performed an exploratory factor analysis on the 54 lockdown items that assessed participants' beliefs, attitudes, and behaviours related to COVID-19 pandemic characteristics and government-imposed lockdown measures[49]. Principal component analysis (PCA) was also performed on the lockdown-related questionnaires, which were answered on a 5-point Likert scale covering statements such as adherence to lockdown instructions, self-medication approach, beliefs around COVID-19, participants' well-being during the pandemic lockdown, individual's non-pandemic health behaviours, belief and perception about the future, level of trust in government, and use of social media during the lockdown.

Cluster analysis was further performed using varimax rotation and Kaiser's criterion normalisation and extraction, with analysis of eigenvalues greater than 1[84]. The outcome of the analysis was plotted *"k"* within 30 iterations for 2, 3, and 6 factors, whereby the cluster analysis of $k = 3$ was chosen as the optimal cluster division for maintaining meaningful population size, as well as in alignment with the previous online survey study[15,49]. The identification of the COVID-19 lockdown group in this study (slightly modified to include the 'comply group', 'sufferer group' and 'defiant group') therefore showed how each grouping characteristic informed the cognitive (specifically, free memory recall), emotional, and neural processes underlying psychological responses to the COVID-19 lockdown rules.

Statistical analyses

Multivariate analysis of variance (MANOVA) was also conducted to analyse the significant differences in the means and effect sizes of COVID-19 lockdown groups, age, and gender on the outcome variables of free memory recall, anxiety, and depression. Furthermore, the associations between lockdown group responses and free memory recall, anxiety, and depression were determined through hierarchical multiple linear regression analysis. Parametric assumptions for all the statistical analyses above were considered and met or adjusted using inferred random sampling, and a sample size normality distribution[85,86] was used before the analyses were conducted. Additionally, running a 4-way MANOVA test comes with added assumptions such as the absence of multicollinearity, no univariate or multivariate outliers, equal population covariance matrices, homogeneity of variance, and multivariate normality residuals for all dependent variables.

Although the homogeneity of variance covariance and part of Levene's test were violated, research has shown that Box's M can be stricter and sensitive to the equality of covariance when the sample size is large; as such, violation of assumptions is not unusual within social science research[87]. Since these two assumptions were thus violated and because of the robust method of MANOVA tests, the interpretation of the statistical tests was derived from Pillai's Trace results rather than from Wilk's Lambda[87,88]. Outliers were statistically analysed using Cook's and Mahalanobis distances of 18.47 for the 4 independent variables. All the assumptions for conducting multiple regression were checked, and all the assumptions were met. The residual errors were further normally distributed and fulfilled for each dependent variable. A stepwise hierarchical multiple linear regression analysis was utilised to depict the stepwise changes in the effect of the prediction between the focal independent variable and demographic variables on the dependent variables[89]. The role of moderation in this study was fundamental, as it assisted in investigating and guiding the predicting effect and explaining 'when' the interactions between differing variables account for the differences in variances of another variable(s) of interest[89,90].

The data analysis was performed using IBM SPSS statistics version 27[91], and the value of alpha (α) was set at 0.05 as a threshold for all the statistical tests, with Bonferroni corrections applied when necessary to account for multiple comparisons. The adjusted alpha level for the Bonferroni comparison was 0.0125, which was further used to assess the level of statistical significance between the dependent variables. A Bonferroni post hoc analysis was performed on all the significant findings to determine the significance of the effects of the independent variables on the dependent variables.

Strengths and limitations

A major strength of this study is that it provides informative data linking COVID-19 lockdown responses and cognitive-emotional performance. This may improve our understanding of public perceptions that consequently inform responses to social isolation measures in the face of a severe viral pandemic. As such, this study was able to add to our understanding of cognitive-emotional processes that are involved in people's behavioural and decision-making responses in the course of prolonged lockdown restriction measures during the pandemic. These data could inform strategies for improving and maintaining individual and group behavioural responses to future pandemics or other global crises. In terms of methodological rigour, the strength of this study was its use of *k*-means cluster analysis to classify the lockdown groups based on similar responses on compliance with lockdown rules[15,49]. The use of *k*-means also assisted in grouping individuals with similar traits to allow for correct analyses and to describe information and patterns that are specific and representative of the group traits within the cluster analysis[92]. Additionally, the use of validated cognitive measures that are theoretically grounded in executive functions and general memory domains[36,42,93], was an additional strength of the study. However, the cultural appropriateness and validation of measures in various country contexts in the Global North and Global South is an additional consideration that can be accounted for in future studies as well. The uneven sample size and very small sample in some countries is a large limitation of the current study. Nevertheless, considering the exploratory nature of the study, the wide representation of the study, especially during a global pandemic, is a strength of the current study. Additionally, given the well-documented Western biases in science, sometimes called WEIRD biases[94] (western, educated, industrialised and rich countries) or Majority world biases[95], having

large representation from non-WEIRD or Majority world countries (e.g., Mexico and South Africa) is an additional strength of the study.

However, our study has a few limitations. First, the primary goal of this study was exploratory, where statistical analyses were designed to explore the relationships between variables of interest. The context of the study was also cross-sectional. Hence, its exploratory nature did not allow us to ascertain precisely defined hypotheses, while its cross-sectional outlook limited the ability to draw causal conclusions from the findings of the study. Future studies should use a longitudinally designed approach to enhance the precise evaluation of cognitive-emotional performance and responses of the sample in relation to COVID-19 lockdown measures. Furthermore, the study is limited by not including personality as a control variable, given its close relationship with free memory recall. Unfortunately, due to the online nature of the study that was conducted during the global COVID-19 pandemic, it was necessary to constrain the number of variables and time of the survey to limit survey fatigue[96]. Future research should explore the dynamics of personality, such as the Big Five personality traits[97,98], and their association with cognitive components, such as working memory and episodic memory.

Another limitation was that despite the large sample size, the total sample could not be determined to be representative of all the nationalities represented. Specifically, there were significant variations in sample representation across the continental regions, with Europe having the dominant sample size, while Africa, Asia, and Australasia were sparsely represented. While the study aimed to include participants from all continents to enhance accessible research participation between the Global North and Global South, it is clear that future research should take additional steps to ensure representative global participation, particularly with a focus on achieving balanced representation from the Global South[99]. With respect to this, caution should be exercised, as the generalisability of the findings to other social structures and cultures is limited.

In conclusion, this study revealed that common global behavioural responses to COVID-19 lockdown measures during 2020 were compliance, suffering, and defiant, and that complying with these rules was associated with better cognitive performance on a recall test. Moreover, those who suffered during the pandemic had greater levels of anxiety, whereas those who were defiant and had greater engagement with social media reported higher levels of depression. Younger females were more susceptible to anxiety. This study further examined the theoretical underpinnings of cognitive processes that inform the 'Unity and Diversity of Executive Function' model, which articulates the conceptual, covariate workings of the executive functions as a unified component, yet individual and distinct in some cognitive functions, and their independent operationalisation in performing certain cognitive tasks[93,100]. In sum, these data may help to provide additional assistance to members of society who might face cognitive and emotional difficulties in response to threats and challenges in future global crises.

Data availability

The data supporting the findings of this study are available on request from the corresponding authors.

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Author contributions

(AO) O., S. N. B., and S. J. (B) conceptualised, analysed, edited, and wrote the main manuscript texts. S. N. B. and S. J. B. provided funding acquisition. S. (A) wrote, edited and aligned the manuscript layout. H. (B) S. conceptualised and facilitated the final version of the manuscript write-up. All authors reviewed the manuscript.

Declarations

Competing interests
The authors declare no competing interests.

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