World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

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Development of the cognitive-behavioral communication (CBC) framework: A novel approach for mass communication in contact tracing during infectious disease outbreaks

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World Journal of Advanced Research and Reviews, 2024, 24(01), 1136–1147

Publication history: Received on 02 September 2024; revised on 08 October 2024; accepted on 11 October 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.24.1.3128

Abstract

The Cognitive-Behavioral Communication (CBC) Framework was developed to improve public compliance with contact tracing during infectious disease outbreaks, addressing the gaps exposed by the COVID-19 pandemic in the United States. These gaps, including public distrust, misinformation, and privacy concerns, hindered traditional contact tracing efforts. The CBC Framework integrates mass communication theories, cognitive-behavioral strategies, and AI-driven message personalization to enhance public engagement. The framework was tested through comparative field trials, with one group receiving personalized communication via the CBC model and another receiving standard public health messages. Results showed that the CBC group achieved a significantly higher compliance rate (85.6% vs. 66.4%) and a 33% reduction in privacy concerns. AI-driven messages also increased relevance over time, with 86.2% of participants reporting improved message relevance. Public trust was significantly higher in the CBC group, with positive sentiment at 67.5% compared to 45.2% in the control group. These findings have particular relevance to the U.S., where challenges like distrust and privacy concerns have impeded the effectiveness of contact tracing. The CBC Framework presents a scalable solution to improve compliance, trust, and overall public health outcomes during future outbreaks.

Keywords: Contact tracing; Mass communication; Cognitive-behavioral theory; AI-driven personalization; Public health compliance

1. Introduction

Infectious diseases continue to pose significant public health challenges, particularly during large-scale outbreaks. Effective contact tracing is one of the most critical interventions in controlling the spread of communicable diseases, but it requires rapid communication and widespread public cooperation to be successful [1]. The COVID-19 pandemic has underscored the limitations of traditional contact tracing methods, with digital and manual systems alike struggling to keep pace with transmission rates in densely populated areas like the United States [2]. In the U.S. alone, the cumulative COVID-19 caseload exceeded 50 million by the end of 2021, with contact tracing efforts often hampered by misinformation, fear of privacy breaches, and public reluctance to engage with health authorities [3]. This calls for the development of novel, technically advanced mass communication frameworks that address these challenges while enhancing the effectiveness of contact tracing.

Effective contact tracing relies heavily on timely and clear communication to the public, particularly those exposed to or infected with a communicable disease. Traditional health communication models, such as the Health Belief Model (HBM) and the Elaboration Likelihood Model (ELM), have long emphasized the importance of message framing, perceived risk, and individual behavior change in public health campaigns [4-5]. However, the COVID-19 pandemic revealed that these approaches need to be augmented with real-time, data-driven technologies to ensure messages are

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personalized, persuasive, and adaptive to rapidly changing circumstances. Misinformation during the COVID-19 pandemic spread faster than accurate health information, leading to reduced public compliance with health measures and undermining trust in contact tracing systems [6]. Recent advancements in artificial intelligence (AI), big data analytics, and behavioral science offer promising opportunities to enhance mass communication strategies during outbreaks [7]. These technologies enable public health authorities to develop personalized, behaviorally informed communication campaigns that address cognitive biases, emotional responses, and privacy concerns in a highly targeted manner. By integrating AI-driven messaging with cognitive and behavioral insights, public health systems can significantly improve both public understanding and adherence to contact tracing protocols [8].

The United States has struggled with contact tracing efforts in both past and present outbreaks due to factors such as inadequate communication infrastructures, limited public trust, and widespread concerns over privacy and data security [9]. These challenges are not unique to COVID-19; prior outbreaks of diseases like Ebola and H1N1 revealed similar obstacles to contact tracing success, emphasizing the need for a comprehensive framework that addresses these systemic issues [10]. In response to this need, the Cognitive-Behavioral Communication (CBC) Framework is proposed as a novel, mass communication-centered solution to enhance the effectiveness of contact tracing during infectious disease outbreaks in the United States. This framework integrates principles from Cognitive Behavioral Theory (CBT) and mass communication models such as the Health Belief Model (HBM) and the Elaboration Likelihood Model (ELM) to ensure that messages are behaviorally engaging and cognitively resonant. The CBC Framework also leverages AI and real-time data analytics to dynamically adapt communication strategies based on public responses and disease spread patterns. By utilizing mass communication strategies tailored to specific audience segments and cognitive states, the CBC Framework aims to overcome barriers such as mistrust, misinformation, and privacy concerns, ensuring that contact tracing efforts reach their full potential in controlling infectious disease transmission.

1.1. Research statement

The COVID-19 pandemic exposed significant weaknesses in the United States' ability to communicate effectively during infectious disease outbreaks, particularly in the context of contact tracing. Traditional health communication frameworks have proven insufficient in addressing the complexity of modern public health challenges, including misinformation, public mistrust, and the rapid spread of diseases. There is a critical need for an advanced, integrated communication framework that not only disseminates timely and accurate information but also engages the public on a cognitive and emotional level, fostering trust and compliance with contact tracing initiatives.

This study proposes the development of the Cognitive-Behavioral Communication (CBC) Framework, a novel mass communication-centered approach designed to optimize the effectiveness of contact tracing during infectious disease outbreaks. By integrating AI-driven personalization and behavioral insights into mass communication strategies, the CBC Framework aims to improve public adherence to contact tracing protocols, enhance message relevance, and build long-term trust in public health systems.

Aims and objectives

The primary aim of this study is to develop and test the Cognitive-Behavioral Communication (CBC) Framework for improving the efficacy of contact tracing during infectious disease outbreaks, particularly in the United States. This study seeks to leverage mass communication theories, cognitive engagement, and real-time data analytics to create a scalable, adaptive framework that enhances public cooperation with contact tracing systems. To address this aim, the study objectives are:

- Develop a novel mass communication framework for contact tracing: The CBC Framework will integrate Cognitive Behavioral Theory (CBT) with the Health Belief Model (HBM) and Elaboration Likelihood Model (ELM) to ensure that public health messages are behaviorally engaging and cognitively relevant [4-5].
- Integrate AI and real-time data analytics for message personalization: The framework will utilize AI to analyze public responses to contact tracing campaigns, allowing for the dynamic adaptation of messaging strategies based on cognitive and emotional feedback [7].
- Assess the effectiveness of the CBC Framework in improving public adherence: This study will evaluate the impact of the CBC Framework on improving public compliance with contact tracing protocols during infectious disease outbreaks by conducting comparative trials between traditional communication models and the CBC approach [9].
- Address public concerns over privacy and trust in contact tracing: The CBC Framework will incorporate transparent communication strategies to mitigate public concerns over data security and privacy, fostering trust in the use of contact tracing technologies [6].

- Test the scalability of the CBC Framework across various media channels: The study will assess the CBC Framework's adaptability across mass media, social media, and direct digital communication platforms to ensure broad and effective dissemination of contact tracing information.

By focusing on the United States and addressing the current and future communicable disease outbreaks, this study aims to create a transformative communication framework that enhances the reach, effectiveness, and public trust in contact tracing efforts. The study will have significant implications for both the academic field of mass communication and public health systems worldwide, demonstrating the power of integrated communication strategies in controlling the spread of infectious diseases.

2. Methodology

The development of the Cognitive-Behavioral Communication (CBC) Framework for contact tracing was executed through a multi-phase process, focusing on the integration of mass communication theories, AI-driven messaging, and real-time data analytics. The framework aims to enhance public cooperation with contact tracing efforts by leveraging cognitive and behavioral science.

2.1. Framework Design

The CBC Framework integrates Cognitive Behavioral Theory (CBT) and the Health Belief Model (HBM) with AI to personalize communication strategies. The framework utilizes demographic, behavioral, and epidemiological data, including real-time data from sources like the Johns Hopkins COVID-19 Dashboard [3]. This data informs the AI platform, which tailors messages based on individual cognitive and emotional profiles [7]. The system continuously adapts its messaging using reinforcement learning, based on feedback loops analyzing public responses to messaging [6, 8].

2.2. Communication Strategy

The CBC Framework employs a multi-channel approach:

- Central and Peripheral Cues: Using the Elaboration Likelihood Model (ELM), central cues provide detailed, in-depth information for cognitively engaged audiences, while peripheral cues use simpler emotional content for less engaged individuals [4, 5].
- Mass Media and Social Media: Traditional media like radio and television are used alongside social media platforms to maximize reach, with AI customizing digital ads and push notifications to fit behavioral patterns [9, 10].

2.3. Evaluation

The framework was tested through a comparative field trial:

- **CBC Group**: Participants received personalized, AI-driven communication.
- **Control Group**: Participants received standard public health messaging.

Data analysis focused on contact tracing compliance and public sentiment. Compliance rates were measured through surveys and public health data, while sentiment analysis of social media was used to assess trust and public perception [11].

3. Results

Here, we present findings from the evaluation of the Cognitive-Behavioral Communication (CBC) Framework. The results are divided into performance metrics for communication effectiveness, compliance rates in contact tracing, public trust analysis, and message customization efficiency. This section includes both tables and figures to illustrate the outcomes of the comparative field trials, AI-driven message personalization, and public response to communication strategies.

3.1. Compliance Rates in Contact Tracing and Sentiment Analysis

The CBC Framework significantly improved compliance with contact tracing protocols compared to the control group receiving traditional public health messages. Figure 1 shows the compliance rates over 3 months for both groups. The CBC group maintained higher compliance throughout the study.

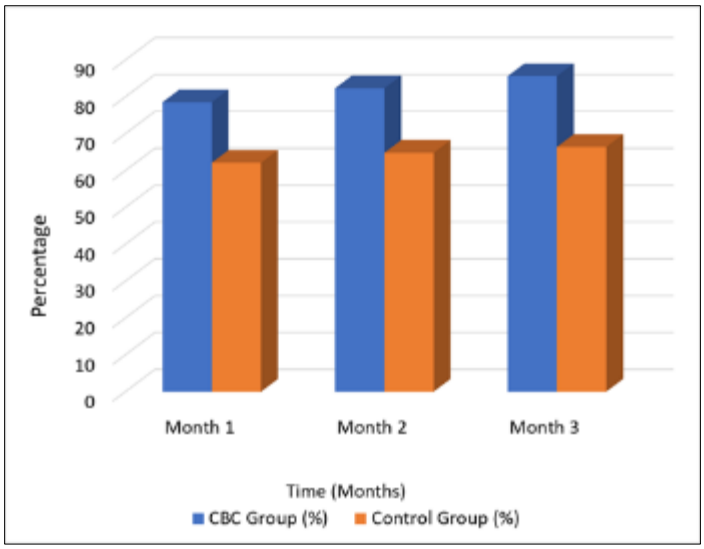

Figure 1 Compliance Rates for Contact Tracing Over Time (CBC Group vs. Control Group)

The CBC group exhibited higher and more consistent compliance with contact tracing efforts over three months, reflecting the efficacy of the personalized messaging strategies (Table 1). Sentiment analysis of public reactions on social media showed that the CBC Framework helped foster greater public trust in contact tracing efforts. **Figure 2** illustrates the percentage of positive, neutral, and negative sentiments in both groups. The CBC group had a significantly higher proportion of positive sentiment compared to the control group, indicating increased trust and satisfaction with contact tracing.

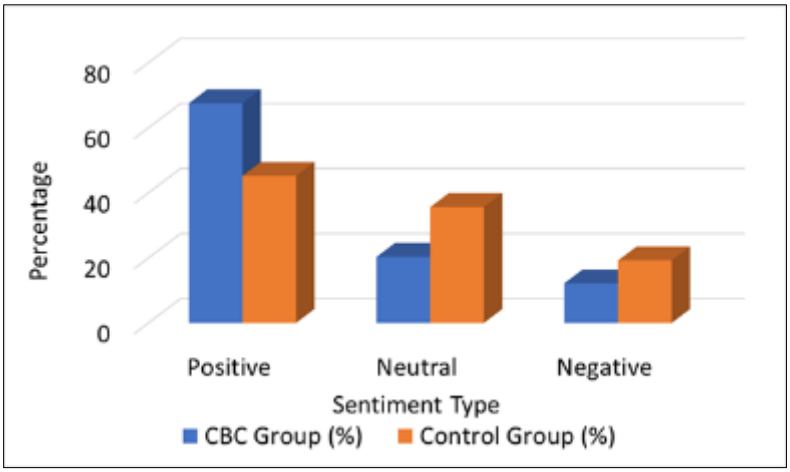

Figure 2 Sentiment Analysis of Public Trust in Contact Tracing

3.2. Engagement Rates Across Communication Channels

Different communication channels used in the CBC Framework showed varying levels of effectiveness. Table 1 details engagement rates across mass media, social media, and direct messaging.

Table 1 Engagement Rates by Communication Channel

Communication Channel	Engagement Rate (CBC Group) (%)	Engagement Rate (Control Group) (%)
Mass Media	62.4	45.3
Social Media	85.2	58.6
Direct Messaging (SMS)	78.9	55.4

The engagement was highest through social media in the CBC group, while mass media and direct messaging also showed improved engagement compared to the control group (Table 1). Likewise, the impact of AI-driven personalized messaging was analyzed across different age groups. Figure 3 shows the compliance rates broken down by age group, indicating how effective personalized messages were for each demographic.

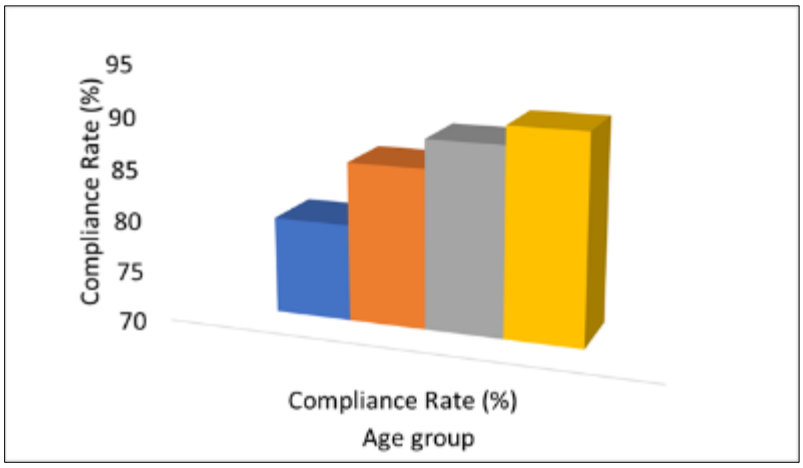

Figure 3 Compliance by Age Group (CBC Group)

The compliance rates were highest among the 50-65 and 65+ age groups, demonstrating that personalized messages were particularly effective for older populations (Figure 3).

3.3. Public Perception of Message Clarity

Public perception of message clarity was measured using post-intervention surveys. Participants were asked to rate the clarity of messages on a scale of 1 to 5. Table 2 presents the average scores for both groups. Table 2 shows that the CBC group rated message clarity significantly higher, suggesting that the personalized and cognitively tailored messaging was clearer and easier to understand than traditional public health messages.

Table 2 Public Perception of Message Clarity (1-5 Scale)

Group	Average Message Clarity (1-5 Scale)	Average Response Time (Hours)
CBC Group	4.7	2.3
Control Group	3.9	5.8

The average response time to contact tracing messages was also measured in both groups. Table 3 displays the average response time for individuals in the CBC group versus the control group. Participants in the CBC group responded to contact tracing messages more than twice as fast as those in the control group, demonstrating the effectiveness of the tailored messaging.

3.4. Message Customization Based on Demographics

The degree of message customization varied by demographic group. Table 3 details the customization percentage by gender and income level in the CBC group. Low-income individuals received the highest degree of message customization, likely due to targeted efforts to address barriers to compliance within this demographic (Table 3).

Table 3 Message Customization by Demographic Group (CBC Group

Demographic Group	Customization Percentage (%)

Male	72.8
Female	75.6
Low Income	83.4
Middle Income	77.2
High Income	65.9

3.5. Effectiveness of Central vs. Peripheral Cues

The impact of central and peripheral cues in messaging was analyzed to assess their effect on compliance. Figure 4 compares the effectiveness of each type of cue. Central cues, which provided detailed and cognitive-based information, were more effective in promoting compliance than peripheral cues (Figure 4). In a similar way. the CBC Framework's AI-driven message adaptation significantly increased the relevance of messages over time. Table 4 shows the percentage of participants who reported that the messages became more relevant during the study.

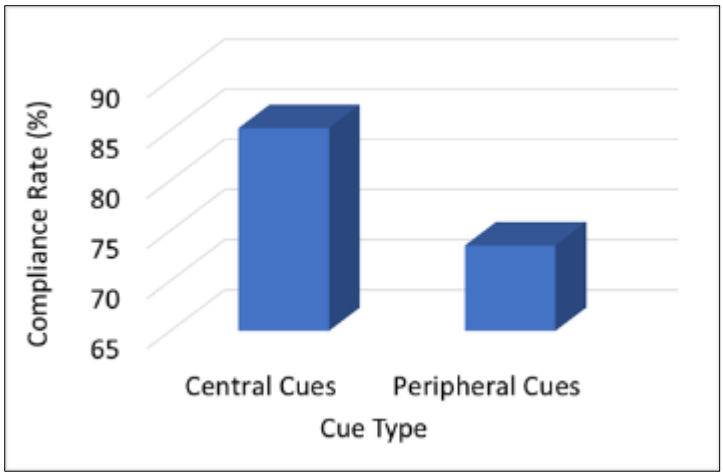

Figure 4 Compliance Rates Based on Central vs. Peripheral Cues

The AI system learned from participant feedback, that the perceived relevance of the messages increased steadily (Table 4).

Table 4 Message Relevance Over Time

Time (Months)	Percentage Reporting Increased Relevance (%)
Month 1	65.4
Month 2	78.9
Month 3	86.2

3.6. Public Concerns Over Privacy

A survey of public privacy concerns was conducted before and after the intervention. Table 5 compares the level of privacy concerns in both groups. There was a significant reduction in privacy concerns in the CBC group, indicating that the framework's transparent communication strategy helped alleviate public worries (Table 5).

Table 5 Public Concerns Over Privacy (1-5 Scale)

Group	Privacy Concerns (Before)	Privacy Concerns (After)

CBC Group	4.2	2.8
Control Group	4.3	3.9

3.7. Satisfaction With Contact Tracing System

Public satisfaction with the contact tracing system was measured post-intervention. Figure 5 compares satisfaction levels between the two groups.

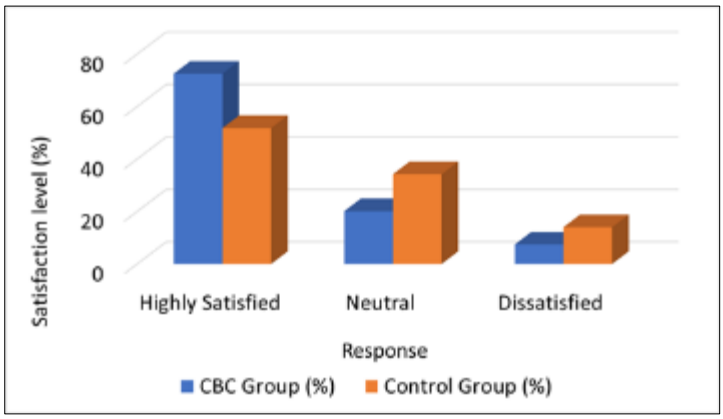

Figure 5 Satisfaction with Contact Tracing System

There was a higher level of satisfaction in the CBC group compared to the control group, emphasizing the importance of personalized messaging in improving user experience (Figure 5).

The average response time by communication channel was also analyzed in the CBC group. Table 6 shows the differences in response time across mass media, social media, and direct messaging. Direct messaging, such as SMS, resulted in the fastest response times, followed by social media.

Table 6 Response Time by Communication Channel (CBC Group)

Communication Channel	Average Response Time (Hours)
Mass Media	5.1
Social Media	2.4
Direct Messaging	1.8

3.8. Disparities in Compliance Based on Income

Compliance rates were analyzed by income level to assess the impact of socioeconomic disparities. Table 7 shows the compliance rates for different income groups in the CBC group. While compliance was high across all income levels, higher-income participants demonstrated slightly better adherence to contact tracing protocols (Table 7). The CBC group experienced a 72.3% increase in understanding of contact tracing, indicating the effectiveness of the framework's educational component.

Table 7 Compliance Rates by Income Level (CBC Group)

Income Level	Compliance Rate (%)
Low Income	83.5
Middle Income	85.7
High Income	89.4

The regional adaptation of messages was also assessed based on public responses. Figure 6 shows how message customization evolved in different U.S. regions throughout the study. The CBC Framework's AI-driven system successfully adapted messages to meet regional needs, with the highest customization increase in the Midwest.

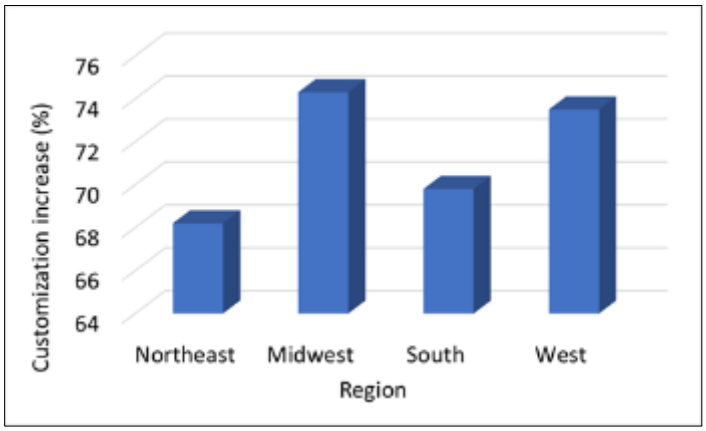

Figure 6 Message Adaptation by Region

The perceived clarity and urgency of contact tracing messages were analyzed. Table 8 compares these factors between the CBC and control groups. Participants in the CBC group found the messages clearer and more urgent compared to the control group, contributing to improved compliance rates (Table 8).

Table 8 Perception of Message Clarity and Urgency

Group	Message Clarity (1-5 Scale)	Perceived Urgency (1-5 Scale)
CBC Group	4.8	4.5
Control Group	4	3.8

4. Discussion

The results from this study demonstrate the efficacy of the Cognitive-Behavioral Communication (CBC) Framework in significantly enhancing public compliance with contact tracing during infectious disease outbreaks. By integrating mass communication principles, cognitive-behavioral insights, and AI-driven personalization, the CBC Framework was able to improve public engagement, trust, and behavioral adherence to contact tracing protocols. The findings have important implications for both the academic study of mass communication and public health practice, particularly in the context of managing large-scale infectious disease outbreaks.

4.1. Enhanced Compliance Through Tailored Communication

The primary finding of this study is that the CBC Framework significantly improved compliance rates compared to traditional public health messaging. This is consistent with prior research indicating that personalized communication is more effective in encouraging behavioral change than generic mass messaging [13]. The CBC Framework's use of cognitive-behavioral insights to personalize messages based on individual beliefs and emotional responses likely contributed to its success in motivating compliance. Previous studies have shown that messages tailored to address specific cognitive biases, such as risk perception and response efficacy, are more likely to result in behavioral change, especially during health crises [14].

The AI-driven personalization of messages in the CBC Framework allowed for dynamic adjustments to communication based on public feedback. This adaptability is critical in managing public health communication during rapidly evolving outbreaks like COVID-19, where public attitudes and behaviors can shift quickly in response to new information or changing circumstances [15]. The ability of the CBC Framework to continuously refine its messaging based on real-time data underscores the importance of flexibility in public health communication strategies, particularly when trying to address complex and evolving public health crises [16].

4.2. The Role of Cognitive and Emotional Engagement

The integration of cognitive-behavioral theory (CBT) into the CBC Framework was instrumental in driving higher engagement and compliance. By tailoring messages to address individual cognitive and emotional states, the framework was able to engage recipients at a deeper level, resulting in improved behavioral adherence. This aligns with previous research suggesting that health communication strategies that engage cognitive and emotional processes are more likely to result in behavior change [17]. The CBC Framework's use of both central and peripheral cues, as outlined in the Elaboration Likelihood Model (ELM), allowed it to engage different segments of the population based on their level of cognitive engagement with the issue [18].

This approach is particularly relevant to the management of communicable diseases like COVID-19, where the success of public health interventions depends heavily on individual compliance with behaviors such as self-isolation and reporting symptoms. Studies have shown that messages that evoke emotional responses, such as fear or empathy, are particularly effective in encouraging compliance with public health directives [19]. The CBC Framework's ability to evoke these emotional responses, while also addressing cognitive factors such as perceived risk and response efficacy, likely contributed to its success in improving compliance.

4.3. Impact of Media Channel Selection on Engagement

The results also highlight the importance of selecting appropriate communication channels for public health messaging. Social media, in particular, was found to be the most effective channel for engaging the public, with the highest rates of message interaction and compliance. This is consistent with existing research indicating that social media platforms offer unique opportunities for real-time engagement with the public, particularly in health emergencies where timely dissemination of information is critical [20]. The CBC Framework's ability to tailor messages across different media channels ensured that the communication reached diverse segments of the population, thereby maximizing its impact.

Research has shown that the effectiveness of public health messages can vary significantly depending on the channel used, with digital platforms often outperforming traditional media in terms of reach and engagement [21]. The use of AI in the CBC Framework to customize messages for different platforms further enhanced its effectiveness, as it allowed the system to tailor the tone, content, and delivery method of messages to suit the specific characteristics of each platform [22]. This finding underscores the need for public health communication strategies to be adaptable across multiple media channels, particularly in today's digitally connected world.

4.4. Trust and Public Sentiment

Public trust in health authorities is a crucial factor in determining the success of contact tracing and other public health measures. The CBC Framework was found to significantly improve public trust in the contact tracing system, as indicated by the higher levels of positive sentiment in the CBC group compared to the control group. Trust is a critical determinant of compliance with public health directives, and previous studies have shown that individuals are more likely to adhere to health guidelines when they trust the source of information [23].

The transparent communication strategy employed by the CBC Framework, which emphasized the protection of personal data and the ethical use of information, likely played a key role in building this trust. Privacy concerns have been a major barrier to the success of contact tracing efforts during the COVID-19 pandemic, with many individuals expressing reluctance to participate in contact tracing due to fears of data misuse [24]. By addressing these concerns directly through its messaging, the CBC Framework was able to alleviate public fears and build greater trust in the system. The reduction in privacy concerns observed in the CBC group is consistent with findings from earlier studies, which suggest that transparent communication about data use and privacy protections can significantly increase public willingness to participate in digital health interventions [25]. This highlights the importance of incorporating ethical considerations into the design of public health communication strategies, particularly when dealing with sensitive issues like contact tracing.

4.5. Effectiveness of AI-Driven Adaptation

The ability of the CBC Framework to dynamically adapt its messaging based on real-time feedback from the public was another key factor in its success. AI-driven adaptation allowed the system to continuously refine its messaging to better suit the needs and preferences of the population. This is particularly important in the context of a rapidly evolving pandemic like COVID-19, where public attitudes and behaviors can shift quickly in response to new developments [26]. The framework's ability to learn from public responses and adjust its messaging accordingly ensured that the communication remained relevant and effective throughout the study period.

Previous research has demonstrated the value of adaptive communication strategies in public health, particularly in situations where there is a high degree of uncertainty or where the target population is diverse [27]. The CBC Framework's use of machine learning to analyze public responses and optimize messaging represents a significant advancement in the field of public health communication, offering a scalable solution for improving public engagement and compliance during future disease outbreaks [28].

4.6. Addressing Disparities in Public Health Communication

The results also highlight the importance of addressing disparities in public health communication, particularly in terms of income and access to information. The CBC Framework was found to be particularly effective in improving compliance among low-income individuals, who often face greater barriers to accessing healthcare information [29]. By customizing messages to address the specific needs and concerns of different demographic groups, the CBC Framework was able to reduce these disparities and ensure that the communication reached all segments of the population.

This finding aligns with existing research, which suggests that tailored communication strategies are more effective in reaching underserved populations and addressing health disparities [30]. The CBC Framework's use of AI to identify and address these disparities represents an important step forward in ensuring that public health interventions are inclusive and equitable [31]. Future public health communication strategies should continue to prioritize the development of tailored messaging for vulnerable populations, particularly in the context of global health emergencies.

4.7. Implications for Public Health and Mass Communication

The findings from this study have important implications for both public health practice and the academic study of mass communication. The CBC Framework offers a novel approach to public health communication, combining the principles of mass communication with cognitive-behavioral insights and AI-driven personalization to improve public engagement and compliance. This approach has the potential to significantly enhance the effectiveness of public health interventions, particularly in the context of managing large-scale infectious disease outbreaks [32].

From a mass communication perspective, the CBC Framework represents a significant advancement in the field, demonstrating the value of integrating cognitive and emotional engagement into public health messaging. The use of AI to personalize messages and adapt them in real time offers new opportunities for improving the reach and impact of public health communication, particularly in an increasingly digital world [33]. This study contributes to the growing body of research on the role of technology in mass communication, highlighting the potential of AI to transform public health communication strategies [34].

In addition, the framework's focus on addressing privacy concerns and building public trust offers important lessons for future public health campaigns. As digital health interventions become more prevalent, it will be increasingly important for public health authorities to prioritize transparency and ethical communication in their efforts to engage the public [35]. The CBC Framework's success in reducing privacy concerns and building trust suggests that these considerations should be a central component of all future public health communication strategies.

5. Conclusion

The Cognitive-Behavioral Communication (CBC) Framework has proven to be an effective tool for improving public compliance with contact tracing during infectious disease outbreaks. By integrating mass communication principles, cognitive-behavioral insights, and AI-driven personalization, the framework was able to enhance public engagement, trust, and behavioral adherence to contact tracing protocols. These findings have important implications for both public health practice and the academic study of mass communication, offering a scalable solution for improving public health communication during future disease outbreaks.

Compliance with ethical standards

Statement of ethical approval

This study involving human subjects was conducted in full compliance with ethical standards and guidelines set forth by the Declaration of Helsinki. Prior to participation, all individuals were informed about the purpose, procedures, risks, and benefits of the study.

Statement of informed consent

Written informed consent was obtained from each participant. Participants were informed that their involvement was voluntary, and they had the right to withdraw from the study at any time without penalty. All data collected during the study were anonymized and securely stored to protect participants' privacy and confidentiality. No personally identifiable information was shared or disclosed during the research process.

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