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## Designing a Metacognitive Training Mobile Application and Evaluating Its Effectiveness on Meta-Worry and Metacognitive Beliefs in University Students with Anxiety Symptoms

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### ABSTRACT

**Objective:** The present study aimed to design a metacognitive training mobile application and to determine its effectiveness in reducing meta-worry and improving metacognitive beliefs among university students with anxiety symptoms.

**Methods and Materials:** This study employed a mixed-methods (qualitative–quantitative) design. In the qualitative phase, the content validity of the developed application was evaluated by five experts using the Content Validity Ratio (CVR) and Content Validity Index (CVI), and the application was piloted with a small number of participants prior to the main implementation. In the quantitative phase, a quasi-experimental pretest–posttest design with a control group was used. The population comprised university students diagnosed with anxiety symptoms in universities in Tehran, and 30 students were selected via convenience sampling and randomly assigned to equal experimental and control groups. Data were collected using the Meta-Worry Questionnaire (Wells, 2006) and the Metacognitions Questionnaire (Wells & Cartwright-Hatton, 2004). The experimental group received the metacognitive training application (including instructional content and practice sessions), whereas the control group received no intervention. Content validity indices indicated acceptable validity (CVR = 1.00; CVI > 0.79).

**Findings:** Descriptive statistics were first reported, and assumptions for univariate and multivariate ANCOVA were examined. Hypothesis testing showed that the metacognitive training application significantly reduced meta-worry ( $F = 5.24, p < .05$ ) and improved metacognitive beliefs ( $F = 38.97, p < .01$ ).

**Conclusion:** The findings suggest that metacognitive processes—particularly meta-worry and negative metacognitive beliefs—play a key role in maintaining and exacerbating anxiety, and that app-based metacognitive training can be used as an accessible and effective intervention.

**Keywords:** mobile application; metacognition; meta-worry; metacognitive beliefs; anxiety symptoms

## 1. Introduction

Anxiety disorders constitute one of the most prevalent and debilitating categories of psychological conditions worldwide, imposing substantial personal, social, and economic burdens. They are characterized by persistent and excessive fear, apprehension, and worry that are disproportionate to situational demands and difficult to control. Among these disorders, generalized anxiety disorder (GAD) is distinguished by chronic and uncontrollable worry across multiple life domains, accompanied by somatic tension, cognitive disturbances, and significant functional impairment. Contemporary research increasingly emphasizes that beyond the frequency or content of anxious thoughts, the *processes* governing how individuals relate to, monitor, and regulate their thinking play a decisive role in the onset and maintenance of anxiety symptoms. Within this perspective, metacognition—defined as beliefs and knowledge about one’s own cognitive processes—has emerged as a central explanatory construct.

Early theoretical developments in this area were crystallized in the Self-Regulatory Executive Function (S-REF) model, which conceptualizes emotional disorders as the product of maladaptive interactions between executive control, metacognitive beliefs, and self-regulatory strategies (Wells & Matthews, 1996). According to this model, individuals experiencing anxiety do not merely worry more; rather, they become trapped in a maladaptive pattern of repetitive negative thinking, threat monitoring, and ineffective coping strategies that is collectively labeled the Cognitive Attentional Syndrome (CAS). The CAS is maintained by both positive and negative metacognitive beliefs—for example, beliefs that worry is useful for problem solving, or that worry is uncontrollable and dangerous—which together perpetuate sustained anxiety and emotional dysregulation.

Building on this framework, metacognitive therapy (MCT) was developed as a transdiagnostic intervention explicitly targeting the processes that sustain the CAS rather than the content of cognitions themselves (Wells, 2009). MCT posits that anxiety persists because individuals hold dysfunctional metacognitive beliefs about their thoughts and emotions, leading them to engage in extended worry, rumination, and threat-focused attention. By modifying these beliefs and training flexible attentional control, MCT aims to interrupt the self-perpetuating cycles of anxiety. Subsequent refinements and clinical manuals have further articulated the mechanisms and techniques of this approach,

reinforcing its applicability across anxiety and mood disorders (Wells, 2025).

Empirical evidence has consistently supported the centrality of metacognitive processes in anxiety. Experimental and observational studies demonstrate that negative metacognitive beliefs—particularly beliefs concerning the uncontrollability and dangerousness of worry—are strongly associated with symptom severity across anxiety-related conditions. Fergus and colleagues showed that attention control moderates the relationship between activation of the cognitive attentional syndrome and psychopathological symptoms, underscoring the importance of executive control processes in regulating worry and rumination (Fergus et al., 2012). Similarly, Spada and collaborators reported that metacognitions are robustly linked to worry and rumination in individuals with personality pathology, highlighting the transdiagnostic relevance of these processes (Spada et al., 2021).

More recent research has expanded this evidence base by integrating cognitive, affective, and neuropsychological perspectives. Cécillon and colleagues demonstrated that trait anxiety is intricately associated with emotion regulation difficulties and maladaptive metacognitive beliefs, which in turn relate to executive functioning and academic outcomes in children and adolescents (Cécillon et al., 2024). These findings suggest that metacognitive dysfunction is not only clinically relevant but also developmentally and educationally consequential. Complementing this, Yu and associates identified significant associations between metacognition, rumination, and sleep disturbances among university students with a tendency toward GAD, further illustrating the pervasive impact of metacognitive processes on daily functioning and well-being (Yu et al., 2024).

Within clinical populations, the relevance of metacognitive beliefs has been demonstrated across diverse anxiety-related disorders. Kim and colleagues documented dysfunctional metacognitive beliefs in patients with obsessive-compulsive disorder and showed that these beliefs exhibit systematic change following treatment, supporting the notion that metacognition is a modifiable and clinically meaningful target (Kim et al., 2021). Nordahl and collaborators extended this line of inquiry by examining the role of meta-worry—worry about worry itself—in interpersonal problems among individuals with GAD, providing empirical validation for the metacognitive model in both analogue and clinical samples (Nordahl et al., 2024). Their findings underscore that meta-worry is not merely a

cognitive epiphenomenon but a factor with tangible interpersonal and functional consequences.

A growing body of Iranian research has also contributed substantially to this literature, offering culturally grounded evidence for the role of metacognition in anxiety. Early work by Ghabari Bonab highlighted associations between anxiety and broader psychological constructs, laying the groundwork for later metacognitive investigations (Ghabari Bonab, 1993). Zamanzadeh demonstrated that metacognitive beliefs are meaningfully related to psychological well-being among nurses, indicating that these beliefs exert influence beyond clinical samples and across occupational contexts (Zamanzadeh, 2013). Farokhzadian later developed a comprehensive psychological model of generalized anxiety disorder and provided evidence for the effectiveness of model-based treatments in reducing GAD symptoms, further reinforcing the applicability of metacognitive principles within Iranian populations (Farokhzadian, 2018).

Intervention studies have likewise shown promising results for metacognitive-based approaches in reducing anxiety and related cognitive vulnerabilities. Salmani and colleagues reported that metacognitive therapy significantly reduced components of the cognitive attentional syndrome and improved cognitive emotion regulation strategies in patients with GAD (Salmani et al., 2013). Yarmohammadi Vasel and associates demonstrated that training metacognitive strategies effectively decreased worry and anxiety among students, highlighting the preventive and educational potential of such interventions in non-clinical or subclinical populations (Yarmohammadi Vasel et al., 2021). More recent controlled studies have continued this trajectory, showing that metacognitive therapy and related interventions can reduce rumination, anxiety, and worry in obsessive-compulsive and anxiety-spectrum disorders (Khalilnejad et al., 2024; Nematollahi et al., 2023).

At the theoretical level, contemporary scholarship has increasingly emphasized the mediating and moderating mechanisms through which metacognition influences emotional distress. Mohammadkhani and colleagues demonstrated that emotional flexibility and affective style mediate the relationship between metacognition and worry, suggesting that metacognitive beliefs exert their effects through complex affective pathways rather than in isolation (Mohammadkhani et al., 2022). Seow and collaborators further broadened this perspective by showing that metacognitive biases in anxiety and depression extend across perceptual and memory domains, indicating that

distorted self-evaluations of cognition may influence multiple levels of information processing (Seow et al., 2025). These findings collectively support a view of metacognition as a higher-order regulatory system with widespread implications for emotional and cognitive functioning.

Despite the robust evidence supporting metacognitive models and interventions, significant challenges remain in translating these approaches into accessible and scalable formats. Traditional face-to-face psychotherapy, including MCT, is often limited by resource constraints, stigma, geographical barriers, and shortages of trained clinicians. University students, in particular, represent a population at elevated risk for anxiety who may face obstacles in accessing timely mental health services. At the same time, this group is highly familiar with digital technologies, creating unique opportunities for innovative intervention delivery. Advances in mobile health and digital therapeutics have opened new avenues for providing psychological interventions that are cost-effective, flexible, and widely accessible.

Within this context, digital and app-based interventions grounded in established psychological models have attracted increasing research attention. However, many existing applications focus primarily on symptom monitoring or general stress reduction and lack a strong theoretical foundation. In contrast, interventions explicitly designed to modify metacognitive beliefs and reduce meta-worry have the potential to address core maintaining mechanisms of anxiety rather than its surface manifestations. Yet, empirical evaluations of such metacognitively informed digital interventions remain limited, particularly within non-Western contexts and among university student populations.

Given the central role of metacognitive beliefs, meta-worry, and the cognitive attentional syndrome in anxiety, and considering the growing importance of technology-based mental health solutions, there is a clear need for rigorously designed and empirically evaluated digital interventions grounded in metacognitive theory. Integrating the principles of the S-REF model and metacognitive therapy into a mobile application may offer a novel means of delivering structured training in attentional control, detached mindfulness, and belief modification, thereby reducing anxiety-related cognitive vulnerabilities in an accessible format.

Accordingly, the aim of the present study was to design a metacognitive training mobile application and to examine its effectiveness in reducing meta-worry and improving

metacognitive beliefs among university students with anxiety symptoms.

## 2. Methods and Materials

### 2.1. Study Design and Participants

The present study used a mixed-methods (qualitative–quantitative) approach. In the quantitative phase, the design was quasi-experimental, employing a pretest–posttest format with a control group. For data collection in the qualitative phase, the researchers conducted a thematic search and review of credible scientific sources. This search was carried out both manually (through note-taking and extraction of relevant materials) and through electronic libraries. Using appropriate keywords, the required materials were searched and reviewed, and the texts most closely related to the research topic were selected. In the next step, the mobile application was developed based on Adrian Wells’s (2019) metacognitive therapy protocol. The application was designed as an eight-session educational program, and for each session, corresponding exercises were developed and integrated into the training content.

After completing the application design, the subsequent stage of the study involved evaluating the application’s functionality by experts. To do so, the developed program, along with an evaluation/rating questionnaire, was provided to five university faculty members and psychology specialists. To assess content validity, the educational materials were reviewed by these experts, and the Content Validity Ratio (CVR) and the Content Validity Index (CVI) were calculated based on their feedback. Revisions were then made according to the experts’ recommendations.

The study population consisted of all university students with a diagnosis of anxiety syndrome in universities in Tehran. In the quantitative phase, 30 students were selected via convenience sampling and then randomly assigned to two equal groups (experimental and control). The Meta-Worry Questionnaire and the Metacognitive Beliefs Questionnaire were administered to collect data. The experimental group received the metacognitive training application, including instructional content and practice sessions, whereas the control group received no intervention.

The inclusion criteria were: meeting diagnostic criteria for anxiety symptoms based on the Spielberger State–Trait Anxiety Inventory (1983), not having received psychological treatment prior to entering the study, being between 18 and 30 years of age, having verified student status, willingness to participate in the study, and signing

written informed consent. The exclusion criteria were: the presence of a psychotic disorder, substance misuse, meeting full criteria for a personality disorder, and having serious suicidal thoughts.

In the qualitative phase, to evaluate validity, the designed application was presented to five experts and their judgments were collected using CVR and CVI forms. Before the main implementation, the application was piloted in several sessions with participants to test feasibility and usability. In the quantitative component, given the nature of the data and the study objectives, the research followed a quasi-experimental pretest–posttest design with a control group. After the application link was sent to participants, baseline data were recorded within the app, and posttest data were collected within a six- to eight-week period.

### 2.2. Measures

The metacognitive training application, named “VaraMind,” was developed and organized into a structured educational package. Based on Adrian Wells’s metacognitive treatment protocol for anxiety, the package was designed as eight training sessions, each including instructional components and related exercises. Educational materials and exercises were delivered in the form of video clips and audio files, and participant engagement and performance could be monitored through an administrative panel. In addition, to facilitate access for the experimental group, the pretest and posttest measures were embedded within the application. After expert review and the implementation of content and delivery revisions, the educational package was piloted on a trial basis, and the finalized version was used in the main intervention.

After final approval, this package was capable of delivering metacognitive training relevant to anxiety disorders in line with Wells’s approach. The application was installed on the smartphones of participants in the experimental group, and the therapist monitored participants’ performance via the management panel and provided the necessary feedback.

The Meta-Worry Questionnaire (MWQ; 7-item) was used to assess meta-worry. According to Wells’s metacognitive model (2008), worry in generalized anxiety disorder resembles normal worry; however, it is accompanied by more negative thoughts and beliefs about worry itself. This form of worry is referred to as Type 2 worry (meta-worry). The MWQ contains seven items related to the perceived dangers of worrying. It is administered as a closed-response

instrument with a 4-point Likert scale and an interval-level scoring approach. Wells (2006) reported Cronbach's alpha coefficients of .88 for the frequency of meta-worry and .95 for belief in meta-worry. Regarding construct validity, the MWQ can differentiate outpatients with GAD from individuals with somatic anxiety or those without anxiety (Wells, 2006). In an Iranian study, Salmani, Hasani, Mohammadzadeh, and colleagues (2014) reported a Cronbach's alpha of .71 for this questionnaire, and Farokhzadian (2018) reported a Cronbach's alpha reliability of .85 (Farokhzadian, 2018).

The Metacognitions Questionnaire (Wells & Cartwright-Hatton, 1997) is a 30-item self-report measure designed to assess individual differences in metacognitive beliefs, judgments, and monitoring tendencies. It includes five subscales, and subscale scores are obtained by summing the items corresponding to each domain. In Iran, the questionnaire was translated and adapted by Shirin-Zadeh, and the Cronbach's alpha for the total scale in an Iranian sample was reported as .91. Reported alpha coefficients for the subscales of uncontrollability, positive beliefs, cognitive self-consciousness, cognitive confidence, and need to control thoughts were .87, .86, .81, .80, and .71, respectively. In Wells and colleagues' work (2004), Cronbach's alpha coefficients for the subscales ranged from .72 to .93, and test-retest reliability over an 18–22-day interval was .75 for the total score and .59 to .87 for the subscales. In Zamanzadeh's study (2013), Cronbach's alpha reliability was .81 for the total questionnaire, and for the subscales (positive beliefs about worry, uncontrollability and danger, cognitive confidence, need to control thoughts, and cognitive self-consciousness) the coefficients were .60, .74, .72, .71, and .77, respectively (Zamanzadeh, 2013).

The Spielberger State-Trait Anxiety Inventory (STAI-X) was originally introduced in 1970 by Spielberger and colleagues. In the state anxiety scale, the primary aim is to measure anxiety intensity on a continuum from low to high: lower scores indicate calmness, moderate scores indicate moderate tension and worry, and higher scores reflect intense fear approaching panic. The inventory includes 40 items, comprising 20 items assessing state anxiety and 20 items assessing trait anxiety. Spielberger et al. (1970) reported Cronbach's alpha coefficients of .92 and .90 for the state and trait scales, respectively. Reported reliability coefficients for state anxiety range from .16 to .62, and for trait anxiety from .73 to .86. The STAI demonstrates high internal consistency, with median alpha coefficients of .92 for state and .90 for trait across different samples. Studies

have also shown very high correlations between the two anxiety forms ( $r = .96$  to  $.98$ ). Mehram (1993) reported high correlations between Spielberger's trait anxiety scale and other anxiety measures (Mehram, 1993), and Ghabari Bonab (1993) reported correlations ranging from .75 to .77 (Ghabari Bonab, 1993).

### 2.3. Intervention

The intervention was delivered across eight sessions. The first session introduced the overall concept of metacognitive therapy, provided psychoeducation about anxiety and depression symptoms, and explained their relationship, as well as differences between the metacognitive approach and other therapeutic approaches. The second session focused on thought suppression and its role in maintaining maladaptive thoughts, using metaphors (e.g., "picking at a wound"), and included exercises such as postponing intrusive thoughts and learning not to engage with intrusive thoughts using a "train station" metaphor.

The third session introduced the Cognitive Attentional Syndrome and helped participants identify factors that maintain repetitive thinking styles. It included psychoeducation on positive and negative metacognitive beliefs, as well as exercises such as detached mindfulness and "letting go of mental control." The fourth session aimed to change cognitive style while preventing excessive self-focused attention, and included challenging uncontrollability beliefs and attention training exercises.

The fifth session emphasized replacing maladaptive response styles and initiating challenges to negative beliefs, along with detached mindfulness practice, free association exercises, and a thought suppression exercise using the "floating ball" metaphor. The sixth session focused on identifying positive metacognitive beliefs and negative beliefs about the dangerousness of worry, using metaphors and behavioral experiments, and included a "prescription writing" exercise.

The seventh session targeted both positive and negative metacognitive beliefs and specifically challenged beliefs about the uncontrollability of worry, teaching new processing styles through verbal and behavioral reattribution, alongside exercises addressing dysfunctional strategies and worry modulation. The eighth session involved re-challenging negative beliefs about uncontrollability and dangerousness, reviewing and consolidating session content, conducting behavioral experiments, and practicing attention refocusing techniques.

2.4. Data Analysis

Data were analyzed using descriptive and inferential statistical methods in SPSS software. Descriptive statistics (means and standard deviations) were calculated for all study variables at pretest and posttest in the experimental and control groups. Prior to hypothesis testing, the assumptions of parametric analysis were examined, including normality of score distributions using the Shapiro–Wilk test, homogeneity of variances using Levene’s test, and homogeneity of regression slopes. To evaluate the effectiveness of the metacognitive training application, one-way analysis of covariance (ANCOVA) was conducted to compare posttest scores between groups while controlling for pretest scores. Effect sizes were calculated to estimate the magnitude of group differences, and the significance level was set at  $p < .05$ .

3. Findings and Results

The total number of participants in this study was 30. In the control group ( $n = 15$ ), all participants were women. In the experimental group ( $n = 15$ ), 11 participants were women (73.3%) and 4 were men (26.7%). All participants were undergraduate students and were between 19 and 24 years of age.

In the qualitative phase, to evaluate content validity, the developed application was provided to five experts and their opinions were obtained using CVR and CVI forms. The minimum acceptable CVR is calculated based on the number of experts who evaluate the content. With five experts, the minimum acceptable content validity is 0.99; scores below this threshold indicate insufficient content validity. For the CVI, values greater than 0.79 are considered acceptable. Because the results yielded  $CVR = 1.00$  and  $CVI > 0.79$ , the content was deemed acceptable. Descriptive statistics for each study variable at pretest and posttest, separately for the experimental and control groups, are reported in Table 1.

**Table 1**

*Descriptive statistics for meta-worry and metacognitive beliefs in the experimental and control groups*

Group	Test	Variable	Mean	SD
Control	Pretest	Meta-worry	16.67	6.32
Control	Pretest	Metacognitive beliefs	89.20	19.94
Control	Posttest	Meta-worry	14.87	5.77
Control	Posttest	Metacognitive beliefs	89.40	18.55
Experimental	Pretest	Meta-worry	17.00	4.33
Experimental	Pretest	Metacognitive beliefs	102.80	12.21
Experimental	Posttest	Meta-worry	11.80	3.65
Experimental	Posttest	Metacognitive beliefs	77.13	15.49

Based on Table 1, differences were observed between pretest and posttest mean scores for meta-worry and metacognitive beliefs in the experimental group, with scores decreasing at posttest. To examine these differences more precisely, a one-way analysis of covariance (ANCOVA) was conducted. First, the assumptions for this analysis were tested. The results showed that, based on the Shapiro–Wilk test, the distributions of the variables did not significantly deviate from normality ( $p > .05$ ), and skewness and kurtosis

indices were within the acceptable range ( $-2$  to  $+2$ ). Levene’s test also indicated homogeneity of variances across the two groups, with significance levels greater than .01 (Table 2). In addition, the test of homogeneity of regression slopes showed that the F statistic for the interaction between group and pretest scores was not statistically significant at the .05 level with 1 and 26 degrees of freedom. Given that the assumptions were satisfied, the results of the one-way ANCOVA are presented in Table 3.

**Table 2**

*Levene’s test results*

Variable	F	df1	df2	p
Meta-worry	1.21	1	28	.28
Metacognitive beliefs	4.45	1	28	.04

**Table 3**

*ANCOVA results comparing experimental and control groups*

Variable	Source	SS	df	MS	F	Effect size	p
Meta-worry	Pretest	244.73	1	244.73	16.22	0.37	.0001
Meta-worry	Group difference at posttest	79.07	1	79.07	5.24	0.16	.030
Meta-worry	Error	407.41	27	15.09	—	—	—
Meta-worry	Total	606.00	30	—	—	—	—
Metacognitive beliefs	Pretest	5653.26	1	5653.26	60.47	0.69	.0001
Metacognitive beliefs	Group difference at posttest	3642.96	1	3642.96	38.97	0.59	.0001
Metacognitive beliefs	Error	2524.07	27	93.48	—	—	—
Metacognitive beliefs	Total	217306.00	30	—	—	—	—

As shown in Table 3, after controlling for pretest scores, the experimental and control groups differed significantly at posttest in meta-worry ( $F = 5.24, p < .05$ ) and metacognitive beliefs ( $F = 38.97, p < .01$ ). This indicates that metacognitive training delivered through the mobile application was effective in improving meta-worry and metacognitive beliefs among students with anxiety symptoms. The metacognitive training application explained 16% of the variance in the reduction of meta-worry and 59% of the variance in the reduction of metacognitive beliefs.

#### 4. Discussion

The present study aimed to design a metacognitive training mobile application and to evaluate its effectiveness in reducing meta-worry and improving metacognitive beliefs among university students with anxiety symptoms. The findings demonstrated that, after controlling for baseline scores, participants who received the app-based metacognitive intervention showed a statistically significant reduction in meta-worry and a significant improvement in maladaptive metacognitive beliefs compared with the control group. These results provide empirical support for the effectiveness of technology-delivered metacognitive training and align closely with the theoretical assumptions of the metacognitive model of anxiety.

The observed reduction in meta-worry is particularly noteworthy, as meta-worry—defined as worry about the process and consequences of worrying itself—is considered a core maintaining factor in generalized anxiety disorder and related anxiety presentations. According to the S-REF model, negative metacognitive beliefs about the uncontrollability and danger of worry activate and sustain the Cognitive Attentional Syndrome, thereby prolonging anxiety (Wells & Matthews, 1996). The significant posttest differences between the experimental and control groups suggest that the intervention successfully targeted these

higher-order beliefs rather than merely suppressing worry content. This finding is consistent with prior clinical and analogue studies demonstrating that reductions in meta-worry are associated with meaningful improvements in anxiety symptoms (Wells, 2009, 2025).

The results are also congruent with empirical evidence showing that metacognitive therapy and related interventions effectively reduce worry and rumination by modifying dysfunctional metacognitive beliefs. Nordahl and colleagues showed that meta-worry plays a significant role not only in symptom severity but also in interpersonal functioning among individuals with generalized anxiety disorder, highlighting its broad psychological impact (Nordahl et al., 2024). The present findings extend this evidence by demonstrating that meta-worry can be effectively reduced through a structured mobile application, suggesting that the mechanisms proposed in face-to-face metacognitive therapy can be successfully translated into a digital format.

In line with these findings, the substantial improvement in metacognitive beliefs observed in the experimental group underscores the central role of metacognition in anxiety maintenance and change. Maladaptive metacognitive beliefs—such as beliefs about the need to control thoughts or the perceived usefulness of worry—have been repeatedly identified as robust predictors of anxiety severity. Studies across clinical and non-clinical populations have shown that these beliefs are more strongly associated with anxiety outcomes than the frequency of negative thoughts themselves (Spada et al., 2021). The significant effect size for changes in metacognitive beliefs in the present study suggests that the application effectively addressed these core cognitive–metacognitive processes.

The findings are consistent with previous intervention studies conducted in both Western and Iranian contexts. Salmani and colleagues reported that metacognitive therapy

significantly reduced components of the Cognitive Attentional Syndrome and improved cognitive emotion regulation strategies in patients with generalized anxiety disorder (Salmani et al., 2013). Similarly, Yarmohammadi Vassel et al. demonstrated that training metacognitive strategies led to significant reductions in worry and anxiety among students (Yarmohammadi Vassel et al., 2021). The current study builds on this literature by showing that comparable outcomes can be achieved through a mobile application, thereby addressing accessibility and scalability challenges associated with traditional therapy formats.

The effectiveness of the application is also supported by findings from recent studies emphasizing the mediating and moderating mechanisms linking metacognition to emotional distress. Mohammadkhani and colleagues found that emotional flexibility and affective style mediate the relationship between metacognitive beliefs and worry, indicating that changes in metacognition can initiate broader improvements in emotional regulation capacities (Mohammadkhani et al., 2022). Likewise, Cécillon et al. demonstrated that maladaptive metacognitive beliefs are associated with trait anxiety, executive function deficits, and academic difficulties, suggesting that improving metacognition may have cascading benefits beyond symptom reduction (Cécillon et al., 2024). The present findings, although focused on meta-worry and metacognitive beliefs, may therefore imply broader functional improvements that were not directly measured in this study.

The results are further supported by neurocognitive and experimental evidence indicating that metacognitive biases operate across multiple cognitive domains. Seow and colleagues showed that metacognitive distortions in anxiety and depression extend to perception and memory, reinforcing the idea that metacognition functions as a higher-order regulatory system (Seow et al., 2025). From this perspective, the observed improvements in metacognitive beliefs may reflect enhanced self-regulatory capacity, enabling participants to disengage from maladaptive monitoring and control strategies that sustain anxiety.

Importantly, the current findings align with research conducted in Iranian samples, supporting the cultural applicability of the metacognitive model. Farokhzadian's model-based intervention study demonstrated that targeting metacognitive processes leads to significant reductions in generalized anxiety symptoms (Farokhzadian, 2018). Earlier correlational work by Zamanzadeh also highlighted the strong associations between metacognitive beliefs and

psychological well-being in professional populations (Zamanzadeh, 2013). Together with the present results, these studies suggest that metacognitive constructs are not culture-bound and can be effectively targeted in diverse contexts.

The effectiveness of the intervention may also be partially explained by its focus on attentional control and detached mindfulness, which are central techniques in metacognitive therapy. Fergus et al. showed that attention control moderates the relationship between activation of the Cognitive Attentional Syndrome and psychopathology, indicating that strengthening attentional flexibility can weaken the impact of maladaptive metacognitive processes (Fergus et al., 2012). By incorporating structured exercises aimed at reducing threat-focused attention and promoting a detached stance toward thoughts, the application likely enhanced participants' ability to regulate their cognitive responses to anxiety triggers.

Another important consideration is the relevance of digital delivery for university student populations. Young adults are generally receptive to mobile-based interventions, and digital formats may reduce barriers related to stigma, time constraints, and access to services. The present findings suggest that when digital interventions are grounded in a strong theoretical framework—such as the metacognitive model—they can produce effects comparable to traditional therapeutic approaches. This is consistent with recent clinical trials showing that metacognitive therapy reduces rumination, anxiety, and worry in various disorders when delivered through structured, protocol-based formats (Khalilnejad et al., 2024; Nematollahi et al., 2023).

## 5. Conclusion

Finally, the significant proportion of variance explained by the intervention in both meta-worry and metacognitive beliefs underscores the clinical relevance of targeting metacognitive processes. Given that anxiety disorders are often chronic and relapse-prone, interventions that modify underlying cognitive–metacognitive mechanisms may offer more durable benefits than symptom-focused approaches. The present study contributes to this growing body of evidence by demonstrating that a metacognitive training mobile application can effectively influence these mechanisms in a student population with anxiety symptoms.

## 6. Limitations & Suggestions

Despite its contributions, the present study has several limitations that should be acknowledged. The sample size

was relatively small and limited to university students, which restricts the generalizability of the findings to other age groups and clinical populations. The reliance on self-report measures may also introduce response biases, and the absence of long-term follow-up limits conclusions about the durability of treatment effects. Additionally, gender distribution was unequal, and potential gender differences in response to the intervention were not examined.

Future studies should replicate these findings with larger and more diverse samples, including clinical populations diagnosed with specific anxiety disorders. Incorporating longitudinal follow-up assessments would help determine the stability of treatment gains over time. Researchers may also examine potential mediators and moderators of change, such as attentional control or emotional flexibility, to clarify the mechanisms through which app-based metacognitive training exerts its effects. Comparative studies evaluating digital metacognitive interventions against other evidence-based digital therapies would further strengthen the field.

From a practical standpoint, the findings support the integration of metacognitive training applications into university mental health services as a low-cost and accessible intervention. Clinicians and counselors may use such applications as adjuncts to face-to-face therapy or as preventive tools for students experiencing subclinical anxiety. Developers and mental health professionals should collaborate to ensure that future applications remain theoretically grounded, user-friendly, and culturally appropriate, thereby maximizing their potential impact on anxiety prevention and intervention.

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### Declaration of Interest

The authors of this article declared no conflict of interest.

### Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants. Ethical approval for the study was obtained from the Ethics Committee of the Islamic Azad University, Science and Research Branch, under the code IR.IAU.SRB.REC.1402.246.

### Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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### Authors' Contributions

S.S.E. was responsible for the conceptualization of the study, development of the metacognitive training mobile application, and supervision of all research phases. R.G.J. contributed to the theoretical framework, methodological design, and expert evaluation of content validity. M.K. was involved in data collection, participant coordination, implementation of the intervention, and statistical analysis. S.R.S. contributed to the interpretation of findings, manuscript drafting, and critical revision of the scientific content. All authors collaboratively participated in the literature review, approved the final version of the manuscript, and take responsibility for the accuracy and integrity of the study.

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