Triggered Screen Restriction Framework: Transforming Gamified Physical Interventions

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***Abstract*—This study examines the effectiveness of the Triggered Screen Restriction (TSR) framework, a novel technique to promote exercise that combines negative reinforcement with adaptive gamification elements. The study examined the TSR framework's impact on physical activity levels, addictive nature, health indicators, psychological factors, and app usability compared to a control group. A mixed experimental design was employed, with 30 participants randomly assigned to either an experimental group using a custom iOS app with the TSR framework or a control group using a similar app without TSR features. Results revealed that the TSR group demonstrated significantly higher physical activity levels ($p < .05$). The TSR framework resulted in significant increases in app usage frequency ($p < .001$). Health indicators showed a significant improvement in balance and stability through the single-leg stance test ($p < .05$), while other health metrics, including maximum jumping jacks completed in one minute, post-exercise heart rate, and body composition, exhibited no significant changes. Analysis of psychological factors revealed a significant increase in perceived competence in the TSR group ($p < .05$), with no significant changes observed in autonomy or relatedness. The TSR intervention demonstrated significantly better usability metrics, including ease of use, system reliability, and perceived usefulness, compared to the control condition (all $p < .001$). The study contributes to the expanding adoption of gamified physical interventions, showcasing the TSR framework as an effective technique for addressing physical inactivity. Future research should explore long-term effectiveness, diverse populations, and integration with wearable devices to further validate and refine the TSR approach in addressing physical inactivity.**

***Keywords*—Gamification; physical activity; negative reinforcement; triggered screen restriction framework; TSR framework; gamified physical intervention**

I. Introduction

Gamification incorporates elements from games into non-gaming settings. Its goal is to boost user engagement, motivation, and participation [1]. Increasingly, gamification is being used in physical activity interventions. Gamified interventions use game-like elements such as badges and rankings to encourage people to be more physically active [2]. Points, for instance, are awarded for task completion, symbolizing achievements. Leaderboards compare users' performances, promoting competition by ranking their achievements. Badges, earned through specific actions, visually represent achievements. Progress is marked by levels, showing advancement, and providing feedback. Challenges are set goals crafted to increase user engagement and active participation. By transforming physical activity into a game-like experience, the gamified intervention aims to increase participation and address the global decline in physical activity and its consequent rise in sedentary lifestyles [3], [4].

Gamification draws inspiration from motivational psychology and strategically employs intrinsic and extrinsic motivators to enhance user engagement in non-game contexts. By embedding some game elements, the intervention stimulates participation through the inherent desire to explore, learn, and enjoy, which indicates intrinsic motivation [5], [6]. Intrinsic motivation promotes self-regulation, as individuals are driven by personal interest instead of external rewards [7], [8]. Conversely, extrinsic motivation makes people do things for external rewards. These rewards can be money or praise from others [9]. The self-determination theory (SDT) helps us understand motivation better. SDT says that individuals have three main needs. These are the need to make choices, to feel capable, and to connect with others. Meeting these needs is key to increasing motivation and overall happiness [10], [11]. Autonomy emphasizes control over one's actions, competence pertains to the ability to navigate challenges effectively, and relatedness indicates a sense of connection with others [12], [13], [14]. Through the lens of SDT, gamification elements such as challenges and points serve as mechanisms to fulfill these innate psychological needs, thereby enhancing motivation and participation in physical activities [5], [15], [16].

A. Gamification Frameworks

The Octalysis framework identifies eight primary motivators for individuals. These motivators encourage individuals to take part in activities. The framework presents these motivators visually as an octagon [17], [18], [19]. It categorizes these motivators into white hat (positive motivations) and black hat (negative motivations) gamification, emphasizing the importance of balancing both for effective gamification.

The Mechanics, Dynamics, and Aesthetics framework encapsulates various game tactics and examination methods. It links game development, analysis, and technological investigation [20], [21], [22]. The Mechanics, Dynamics, and Aesthetics framework divides games into three main parts. Mechanics are the core elements and algorithms of the game. Dynamics refer to how the mechanics respond to player inputs in real-time. Aesthetics involve the emotional reactions of players.

The Sustainable Gamification Design framework aspires to create gamified systems with long-lasting benefits. It focuses

on three main areas. These are user activity, environmental influence, and social commitment [23], [24], [25], [26]. The Sustainable Gamification Design framework contains four key stages: Discover, Reframe, Envision, and Create, emphasizing moral and human-centered layout guides throughout the process.

The FRAGGLE framework is an agile method. The FRAGGLE framework aims to improve learning experiences through gamification. This framework aligns gamified actions with educational objectives, content, and assessment measures [27], [28], [29]. The framework has four main phases. These phases are Declaration, Creation, Execution, and Learning. The framework focuses on making gamified activities that are both engaging and educationally effective.

The growing interest in gamification for promoting physical activity presents a promising opportunity. A novel framework can be molded to encourage exercise. The novel framework can address specific needs and motivations. It can do so by using negative reinforcement. By incorporating gamification elements, this innovative approach has the prospect of boosting the acceptance of healthy habits significantly.

B. The TSR Framework

The TSR framework offers a new strategy for implementing gamification elements in exercises. It addresses the limitations of traditional methods [30]. This framework combines adaptive gamification strategies, machine learning models, and computer vision. It creates an intriguing and personalized experience to promote physical exercise. The TSR framework stands out due to its unique features. These include negative reinforcement, adaptive gamified components, and real-time action verification that respects privacy [31].

The primary technique of the TSR framework leverages individuals' Fear of Missing Out (FOMO) and employs negative reinforcement to enhance motivation. It restricts entry to social media apps based on exercise objectives. This technique harnesses people's urge to remain connected and educated. Physical activity becomes essential to access restricted venues [32]. The TSR approach also includes customized message triggers. It uses a model of computer vision to exercise recognition. The adaptive incentive system adjusts the difficulty level based on each user's established routine [31].

The TSR framework builds on existing research on gamified physical interventions. It adds new elements to overcome common limitations. We need to explore several areas to understand the TSR framework's contributions fully. These include the current landscape of gamified physical interventions, how negative reinforcement affects behavior change, and the addictive nature of electronic devices. The next section reviews related work in these areas. This process provides context for the TSR framework's unique approach and its potential to promote physical activity.

II. Related Work

A. Gamified Physical Interventions

A gamified intervention incorporating points, progress bars, challenges, and leaderboards was investigated for its effects on daily step counts. The results indicated a significant increase in steps taken by participants during the intervention period [33], [34], [35].

Researchers conducted a controlled trial study using a gamified physical intervention on overweight adults. The intervention used a fitness tracker and a smartphone app. It gave game-like feedback, helped set goals, and offered social support. The study found that during the intervention, participants took more steps. However, this increase did not last after the intervention ended [36], [37], [38].

Researchers investigated a gamification-based intervention designed to encourage walking among obese adults. The results indicated that participants who engaged with the gamified elements of the intervention increased their walking frequency [39], [40], [41].

The efficacy of gamification in enhancing physical activity was examined using a commercially available activity tracker coupled with a custom-designed mobile app. The gamified intervention, which incorporated points, leaderboards, and social interaction features, significantly increased step counts [42], [43].

A gamified intervention utilizing challenges and self-monitoring tools was designed to encourage physical activity in adults. The study identified a significant positive effect of the gamified intervention in increasing participants' daily step counts [44], [45].

The use of a gamified social media intervention delivered through WeChat was examined to promote physical activity. The intervention utilized various game mechanics, including competition, points, and social interaction, to encourage walking. The findings demonstrated that the intervention effectively increased participants' daily step counts [46].

The long-term effects of a gamified intervention on physical activity maintenance were investigated. The intervention involved points, progress bars, competition, and financial rewards, leading to a significant increase in step counts. Notably, the positive effects persisted for a two-year follow-up period, emphasizing the potential for long-term behavioral change [47], [48].

Researchers investigated a gamified intervention to increase walking in overweight and obese adults. They used the Way to Health platform. Even though the program had game-like features, it did not lead to participants walking more [49].

Researchers assessed the impact of an app with game-like features to encourage adults to be more active. The app used points, progress bars, challenges, rankings, and rewards. The study found that participants using the app became more physically active [50].

A gamified app employing points, progress bars, challenges, and social interaction elements was created to encourage physical activity. The results showed a notable rise in physical activity among users who utilized the gamified app [51].

Researchers studied the impact of the game-like features to promote exercise. The intervention used points, progress bars, and challenges. The study showed that participants who used gamified physical intervention apps exercised more [51].

A study examined the long-term impact of a gamified cycling exercise. Despite using points and progress bars, the study did not show significant long-term significance on cycling activity [52].

The related studies analyzed the prospect of gamified physical interventions. Many of the mentioned gamified physical interventions overly rely on positive reinforcement, which led to a decline in activity levels post-intervention.

B. Negative Reinforcement

Negative reinforcement makes a behavior more likely to happen again by removing unwanted provocation. Understanding how negative reinforcement affects an individual's motivation to initiate new behaviors or tasks is crucial for education, therapy, and behavior modification applications.

Reinforcement theory implies that behavior can be modified through reinforcement. Negative reinforcement is one of the four primary strategies in reinforcement theory, alongside positive reinforcement, punishment, and extinction. It is effective in increasing desired behaviors by eliminating negative conditions, but it must be carefully managed to avoid unintended results [53], [54]. Combining positive and negative reinforcement is very effective in boosting task compliance and decreasing escape-maintained damaging behavior [55], [56]. The frequency of negative reinforcement can moderately affect the persistence in completing tasks. This implies that regular use can sustain desired behaviors over time [57].

Negative reinforcement can lead to distinct emotional responses, such as increased positive affect and reduced fatigue, which may influence motivation and feedback processing in organizational settings [58]. The negative reinforcement paradigm can be effectively used in classroom settings to increase desirable behaviors and decrease undesirable ones, suggesting its potential applicability in training and development programs [59].

Teachers and therapists can use negative reinforcement effectively to increase treatment integrity and compliance with interventions. A study has demonstrated that combining performance feedback with negative reinforcement improves implementation accuracy and reduces off-task behavior among students [60]. Interventions based on negative reinforcement can be customized to fit individual needs. This customization boosts their effectiveness in behavior modification programs [61].

C. Addictive Nature of Electronic Devices

The addictive nature of electronic devices, particularly smartphones, is a growing concern. Smartphone features like infinite scroll and autoplay facilitate the perception of reinforcement rewards and promote habit formation, which together drive smartphone addiction [62]. Users often spend more time than planned on applications with infinite scrolling due to the psychological effects of the feature, leading to increased dependency on these applications [63].

FOMO greatly contributes to the addictive nature of electronic devices. FOMO is linked with the destructive effects of social media on everyday life and job performance, with various social media use disorders acting as intermediaries [64]. FOMO causes people to frequently check their phones and can predict no-mobile-phone phobia [65]. No-mobile-phone is a contemporary psychological condition marked by the fear of not having a mobile phone [66]. It also mediates between psychological needs and phubbing, strengthening the habit of constantly checking smartphones [67].

Perceived enjoyment, emotional gain, and social pressure greatly contribute to smartphone addiction. Enjoyment from using smartphones can create habitual usage, which then leads to smartphone addiction [68]. Emotional gain, which includes positive emotions and relief from negative psychological states, is a strong predictor of smartphone addiction across generations [69].

Social media interactions offer positive reinforcement (for instance, likes and comments) and negative punishment (such as social comparison). The positive and negative factors contribute to social media dependence [70]. Individuals with social anxiety and loneliness are more prone to smartphone addiction, especially when their primary use is accessing social networking sites [71].

The extensive use of smartphones for social interactions and process-related activities, such as browsing and gaming, significantly contributes to habitual and addictive smartphone behavior [72], [73]. Younger generations exhibit higher levels of smartphone addiction compared to older generations, with emotional gain and social environment pressure being strong predictors of this behavior among younger users [74], [69].

III. Objective

The study aims to thoroughly assess the TSR framework, a novel gamification framework to promote physical activity. It will compare the TSR framework with a control group that undergoes a gamified physical intervention without using the TSR framework. The study seeks to determine whether the TSR framework leads to significant improvements in physical activity levels, health metrics, and psychological aspects. Additionally, it aims to evaluate the framework's impact on app usability and its potentially addictive nature. The study examines changes in psychological aspects such as autonomy, competence, and relatedness among participants using surveys conducted before and after the intervention. Furthermore, the study evaluates participants' experiences with the gamified physical intervention, focusing on the ease of use, system reliability, and usefulness of the TSR framework in promoting physical activity.

IV. Methodology

The study employed a mixed experimental design with between-subjects and within-subjects components to assess the effectiveness of the TSR framework in enhancing physical activity and health outcomes. Participants were randomly assigned to either an experimental group using a custom iOS app with the TSR framework or a control group.

A. Participants

Following Institutional Review Board approval, 30 participants (19 to 38 years old, M = 29.56, SD = 5.25)

were recruited from Iowa State University students and residents (see Table I). Participants were healthy adults without pre-existing medical conditions that could hinder physical activity. Recruitment was conducted through campus flyers and snowball sampling. Participants were informed that their involvement was voluntary and that they could withdraw at any time without consequences.

TABLE I. PARTICIPANT DEMOGRAPHICS

Characteristic	Category	Percentage
Education	Graduate degree	53%
	Bachelor's degree	30%
	High school diploma	17%
Employment Status	Employed full-time	60%
	Unemployed	3%
	Students	37%
Used Gamified Apps Before	Yes	53%
	No	47%
Competitive Features	Yes	77%
	No	23%

B. Procedure

1) Orientation and group assignment: All participants attended an orientation session. They learned about the study's goals and steps. Then, they were split into two groups randomly. The experimental group used a custom-made iOS app with the TSR framework. The control group used the same app but without the TSR framework.

2) Intervention period: The study duration was four weeks. During the study, both groups were asked to do jumping jacks daily using the given app. The app logged the number of repetitions for each participant.

3) Data collection: Participants attended two in-person sessions at the ATHENA Lab, located at 0066 Black Engineering, ISU, for measurement of stamina and physique indicators (maximum jumping jacks in one minute, post-exercise heart rate, single-leg stance test, and body composition). Psychological factors and app usability were assessed through surveys on a secure device in the lab.

4) Data management: Data was de-identified at the point of collection, with all measures associated with assigned study ID codes rather than participant names or contact information.

5) Debriefing: All participants were fully debriefed about the true nature of the research and the importance of having a control group. In the debriefing session, participants were informed of the experiment's aim to compare the effectiveness of a gamified physical intervention with and without the TSR in boosting physical levels and improving health outcomes. The research team explained that the deception was needed to avoid potential biases and ensure the study results were valid. Participants were encouraged to ask questions and share any concerns about the deception or the study in general. The research team addressed these questions and concerns openly and honestly.

C. Apparatuses

The study utilized several apparatuses to measure participants' health metrics and facilitate the experimental procedures. Body composition, including muscle mass and fat percentage, was assessed using the eufy by Anker, Smart Scale P1. This smart scale provides accessible body composition measurements, allowing for tracking changes in muscle mass and fat percentage throughout the visits. The study used the FACEIL Pulse Oximeter Fingertip, a non-invasive device that measures heart rate and oxygen saturation levels to measure the heart rate. The pulse oximeter measured participants' heart rate immediately after the one-minute jumping jacks exercise and at one, two, three, and four minutes post-exercise to assess cardiovascular recovery. An iPhone 14 Pro was used to precisely time the one-minute jumping jacks exercise and the post-exercise heart rate measurements, ensuring consistency and accuracy in the data collection process.

D. Measurements

The study assessed various variables to measure the significance of the TSR framework:

1) Addictive nature: Number of times the app was opened by each user.

2) Physical activity metrics: Number of jumping jack repetitions.

3) Health indicators: Maximum jumping jacks in one minute, post-exercise heart rate, single-leg stance test, and body composition.

4) Psychological factors: Autonomy, competence, and relatedness.

5) App usability measures: Ease of use, system reliability, and perceived usefulness.

The surveys were administered in person at the ATHENA Lab. Participants completed the surveys on a secure device provided in the ATHENA lab. These surveys were designed to collect participant responses securely and confidentially. All the surveys had the same Likert scale. Participants fill out 5-point questionnaires varying from "Disagree" to "Agree". The surveys were adjusted to ensure no personally identifiable information (like names or email addresses) was collected with the responses.

The scales measuring psychological factors (autonomy, competence, and relatedness) were adapted from previously validated instruments, the Basic Psychological Needs in Exercise Scale (BPNES) [75]. The app usability scales were also based on established usability questionnaires, the Technology Acceptance Model (TAM), [76] [77].

In prior studies, these validated scales showed strong psychometric indicators, such as high internal consistency reliability and construct validity. By employing these validated scales, the study ensured that the psychological factors and app usability measures were reliable and valid, allowing for meaningful interpretation of the results.

The physical activity metrics and health indicators were considered objective measures. Their validity was assumed based on the accuracy of the app's logging system and the standardized protocols used for the jumping jacks test, single-leg stance test, and body composition assessment.

V. Result

All data were analyzed using JASP version 0.18.3. We employed both independent samples t-tests and repeated measures ANOVA to assess differences in our outcome measures. Independent samples t-tests were used to evaluate between-group differences, while repeated measures ANOVA was utilized to analyze changes over time and interactions between time and app mode (TSR framework vs. control). Tukey's HSD test was used for post-hoc comparisons to evaluate our hypotheses. As the results were qualitatively consistent across both parametric and non-parametric methods, we present the t-test and ANOVA results due to their familiarity to most readers and their established robustness against violations of normality and homogeneity of variance, particularly when sample sizes are equal across treatment groups, as is the case in our study [78], [79].

A. Addictive Nature

H1. The TSR framework leads to a significant increase in app usage frequency compared to a gamified physical intervention without the TSR framework.

An independent samples t-test was conducted to evaluate the impact of the TSR framework on app usage frequency. The analysis revealed a significant difference in app usage between the experimental group and the control group [$t(28) = -5.552$, $p < .001$]. Participants in the experimental group ($M = 3.112$, $SD = 1.642$) opened the app significantly more often than those in the control group ($M = 0.626$, $SD = 0.558$). These results suggest that the TSR framework significantly impacts the addictive nature of the intervention, which resulted in higher usage frequency (see Fig. 1).

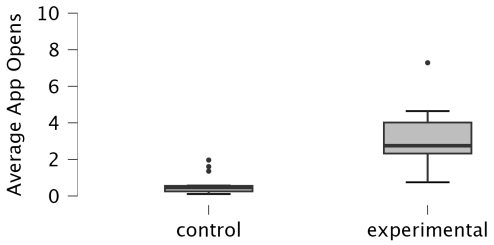

Fig. 1. Average app usage frequency by group.

B. Physical Activity Levels

H2. The TSR framework leads to a significant improvement in physical activity levels among participants compared to a control group without the TSR intervention.

An independent samples t-test was conducted to evaluate the impact of the TSR framework on physical activity levels, measured by the average number of repetitions performed. The analysis revealed a significant difference in repetitions between the experimental group and the control group [$t(28) = -2.346$, $p < .05$]. Participants in the experimental group ($M = 12.721$, $SD = 18.825$) performed significantly more repetitions on average than those in the control group ($M = 1.267$, $SD = 1.754$). These results suggest that the TSR framework significantly impacts physical activity levels (see Fig. 2).

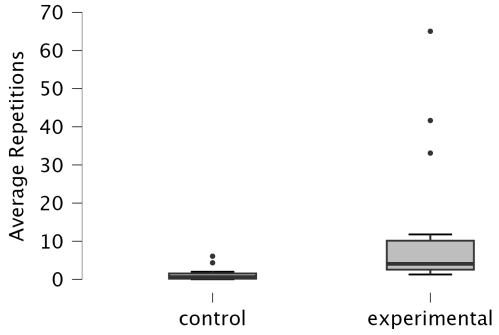

Fig. 2. Average exercise repetitions by group.

C. Health Indicators

H3. The TSR framework leads to a significant improvement in health metrics among participants compared to a control group experiencing a gamified physical intervention without the TSR framework.

Repeated measures ANOVA was performed to assess the effect of the intervention on all health metrics: maximum jumping jacks completed in one minute, post-exercise heart rate, single-leg stance test, and body composition. The analysis revealed a significant interaction between time and app mode in the within-subject effect for the Single-leg stance test [$F(1, 28) = 5.572$, $p < .05$]. The between-subjects analysis also showed a significant main effect of app mode for this test [$F(1, 28) = 7.509$, $p < .05$]. Post hoc comparisons using Tukey's HSD test revealed a significant difference between the before and after intervention scores for the experimental group (Mean Difference = -50.167, $p < .05$), while the control group showed no significant change. These results suggest that the TSR framework significantly improved balance and stability as measured by the Single-leg stance test. No significant changes were observed in the other health metrics.

D. Psychological Factors

H4. The TSR framework leads to a significant improvement in perceived psychological factors in physical activities compared to a gamified physical intervention without the TSR framework.

Repeated measures ANOVA was performed to assess the effect of the intervention on all psychological factors: autonomy, competence, and relatedness. The analysis revealed a significant main effect of time [$F(1, 28) = 7.303$, $p < .05$] and a significant interaction between time and app mode [$F(1, 28) = 4.534$, $p < .05$] for competence. Post hoc comparisons using Tukey's HSD test showed a significant increase in competence scores for the experimental group from before to after the intervention (Mean Difference = -0.656, $p < .05$), while the control group showed no significant change. These results suggest that the TSR framework significantly improved perceived competence in physical activities (see Fig. 3). No significant changes were observed for autonomy or relatedness.

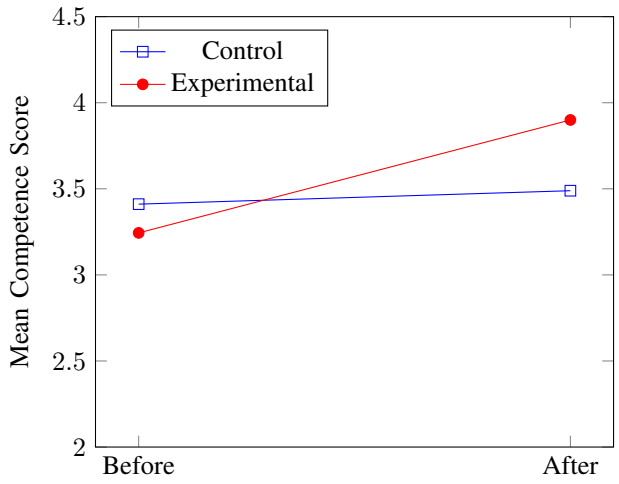

Fig. 3. Changes in competence scores before and after intervention.

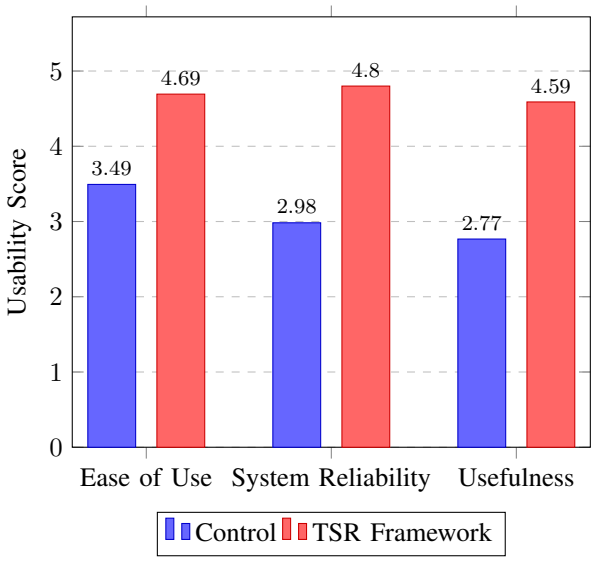

Fig. 4. Comparison of intervention usability factors between control and TSR framework groups.

E. App Usability

H5. The TSR framework leads to a significant improvement in perceived app usability compared to a gamified physical intervention without the TSR framework.

Independent samples t-tests were performed to assess the effect of the intervention on all intervention usability factors: ease of use, system reliability, and perceived usefulness. The analyses revealed significant differences between the experimental and control groups for all three factors. For perceived ease of use, a significant difference was found [t(28) = -4.372, p < .001], with the experimental group (M = 4.693, SD = 0.369) reporting higher scores than the control group (M = 3.493, SD = 0.997). Perceived system reliability also showed a significant difference [t(28) = -6.864, p < .001], with the experimental group (M = 4.800, SD = 0.330) scoring higher than the control group (M = 2.983, SD = 0.970). Similarly, perceived usefulness demonstrated a significant difference [t(28) = -5.042, p < .001], with the experimental group (M = 4.589, SD = 0.620) reporting higher scores than the control group (M = 2.767, SD = 1.255). The usability analysis shows the TSR framework intervention outperformed the control intervention in ease of use, reliability, and perceived usefulness. Participants reported it more user-friendly, reliable, and valuable for their physical activity goals, potentially boosting engagement, program commitment, and health outcomes (see Fig. 4).

VI. Discussion

This research offers important insights into the effectiveness of the TSR framework. The TSR approach to gamified physical interventions has shown promising results. The study's findings demonstrate notable improvements across several measures. However, the research also identifies specific areas that require additional investigation and refinement.

The significant increase in physical activity levels, as measured by jumping jack repetitions, in the experimental group compared to the control group aligns with previous research on gamified interventions for physical activity [33], [42], [44]. This result indicates that the TSR framework's unique approach effectively boosts users' engagement in physical exercise.

The analysis of app usage frequency revealed a significant increase in the number of times users opened the app in the experimental group compared to the control group. This finding supports the statement that through its innovative use of FoMO and negative reinforcement, the TSR framework might create an engaging and might lead to habit-forming intervention. The substantially higher usage frequency demonstrates the framework's success in leveraging addictive features to promote regular engagement with physical activities. By channeling the compelling nature of digital interactions into health-promoting behaviors, the TSR framework shows promise in transforming potentially problematic usage patterns into sustained, healthy habits.

Regarding health indicators, the significant improvement in the single-leg stance test for the experimental group is particularly noteworthy. The enhancement in balance and stability suggests that the TSR framework may offer benefits beyond just increasing activity levels, with potential implications for some physical functions. However, the lack of significant changes in other health metrics, including maximum jumping jacks completed in one minute, post-exercise heart rate, and body composition, indicates that the framework's impact on broader health outcomes may be limited, at least within the time frame of this study.

The analysis of psychological factors revealed interesting outcomes, particularly in terms of perceived competence. The significant increase in competence scores, especially evident in the experimental group, suggests that the TSR framework effectively boosts users' confidence in their ability to engage in physical activities. However, the lack of significant changes in autonomy and relatedness scores indicates that these aspects of psychological need satisfaction may require further refinement within the TSR framework.

The intervention usability measures strongly supported the

TSR framework's effectiveness in terms of user experience. Significant improvements were observed in ease of use, system reliability, and perceived usefulness compared to the control intervention. The findings highlight the importance of user experience in promoting engagement with gamified physical interventions and suggest that the TSR framework successfully addresses key aspects of technology acceptance [77].

The research findings should be interpreted with caution due to certain constraints in the study design. A key limitation was the restricted number of participants involved, which may have affected the statistical power of the analysis. Additionally, the shortness of the experimental time frame could have obscured some outcomes, particularly for health-related metrics that typically necessitate longer observation periods to manifest noticeable changes. Finally, the lack of social features and the use of machine-learning techniques may have resulted in a lack of improvement in some factors, especially autonomy and relatedness.

Nevertheless, the research offers compelling evidence for the potential of the TSR framework in promoting physical activity and improving specific health outcomes. The framework's ability to significantly increase user engagement, improve balance and stability, enhance perceived competence, and provide a superior user experience suggests that it offers a promising approach to addressing physical inactivity.

VII. Future Work

The promising results of this study on the TSR framework highlight several avenues for future research and development:

1) Long-term effectiveness: Future studies should investigate the TSR framework's ability to sustain behavior changes over extended periods. A longitudinal study lasting several months could provide valuable insights into whether the framework can maintain increased physical activity levels and the improved health indicator observed in this study. The long-term direction addresses a common challenge in health interventions and could help validate the long-term impact of the TSR approach.

2) Diverse populations: Future research should include a broader range of participants, including different age groups, fitness levels, and backgrounds. Testing the TSR framework with older adults, children, or people with specific health conditions would enhance the generalizability of the findings and potentially reveal how the framework's effectiveness varies across different demographics.

3) Varied physical activities: While the current study focused on jumping jacks, future studies should explore the framework's efficacy with a wider range of physical activities. Future studies could include aerobic exercises, strength training, or sports movements, providing insights into the versatility and broader applicability of the TSR framework across different types of physical activity.

4) Psychological factors refinement: Given the significant improvement in perceived competence but lack of change in autonomy and relatedness, future work should focus on enhancing the TSR framework to better support all aspects of psychological need satisfaction. This might involve incorporating more personalized goal-setting features or embracing social interaction elements to address autonomy and relatedness more effectively.

5) Health indicators assessment: The lack of significant changes in most health indicators, except for the single-leg stance test, suggests a need for more comprehensive and possibly longer-term health assessments. Future research could employ more sensitive measures of cardiovascular fitness, muscular strength, and body composition. Additionally, adjusting the framework's intensity and duration of physical activities might lead to more substantial health improvements.

6) Addictive nature analysis: While the increased app usage frequency demonstrates the TSR framework's effectiveness in engaging users, further research is needed to explore the long-term implications of this engagement. Studies could investigate how the framework's addictive features translate into sustained healthy behaviors over time and examine potential strategies to optimize engagement without introducing problematic usage patterns.

7) Wearable device integration: Future work could explore combining the TSR framework with popular wearable fitness devices. The integration with wearable devices could provide more accurate activity tracking and personalized feedback, potentially enhancing the framework's effectiveness and user experience even further.

VIII. Conclusion

The study provides strong evidence for the effectiveness of the TSR framework as an innovative approach to gamified physical interventions. The results demonstrate that the framework's unique features can significantly impact physical activity levels and certain health indicators. Key findings of the study include:

- A significant increase in physical activity levels in the experimental group, as measured by jumping jack repetitions, compared to the control group.
- Significantly higher app usage frequency in the TSR framework group, demonstrating the framework's success in leveraging addictive features to promote regular engagement with physical activities.
- Improved balance and stability in the TSR framework group, evidenced by significant improvements in the single-leg stance test.
- Increased perceived competence among participants using the TSR framework, while no significant changes were observed in autonomy and relatedness.
- Superior user experience with the TSR framework intervention, with significantly higher ratings in ease of use, system reliability, and perceived usefulness compared to the control intervention.

In conclusion, the TSR framework addresses several limitations of conventional gamified physical interventions by using negative reinforcement and incorporating adaptive gamification elements. The TSR approach shows promise in creating a more engaging, potentially habit-forming method for promoting physical activity. The framework offers an innovative and impactful approach to encouraging healthier,

more active lifestyles. The TSR framework has been demonstrated as an effective method for tackling physical inactivity, contributing to the broader implementation of gamified physical interventions.

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