ISSN:1738-6764, eISSN:2093-7504

Identifying Stress-Inducing Elements of User Interfaces: A Literature Review

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https://doi.org/10.5392/IJoC.2025.21.3.001

Manuscript Received 26 November 2024; Received 18 June 2025; Accepted 4 July 2025

Abstract: *Stress can arise even with the effective use of a product, and it can cause negative emotions and affect the mind and body in different ways. This study focuses on stress caused by interacting with digital products and which specific elements of user interfaces could induce stress and result in its known negative consequences. Previous studies and cases discussing some relation between user interfaces and stress were reviewed to identify elements that could cause stress to users while interacting with digital products. After merging similar and overlapping concepts, eleven final stress-inducing elements associated to 4 different categories (User Experience, Usability, Psychophysiology of Stress and Interface Visual Design) were identified, defined and exemplified: Content Overload, Service Instability, Low level of Attractiveness, Lack of Control, Low level of Safety, Low Usability, Unpredictability, Uncertainty, Unfamiliarity, Judgment or social evaluation threat and Poor Visual Design. This set of elements could help design better interfaces while taking into consideration users' mental and emotional state.*

Keywords: Stress; User Interface; User Interface Design; UI; UI Design

1. Introduction

As times evolve, technology and digital products become more and more prominent in our everyday lives. From using computers and smartphones to wearable devices and kiosks, we are interacting with them through different interfaces all the time.

When studying the design of digital products, we often learn that a good user interface (UI) design is necessary to help users achieve their goals effectively and efficiently. On the other hand, poor design is linked to negative emotions and frustration in users, failure to complete their goal(s), abandonment of the system, low conversion rates, etc.

Stress is known to be a response to mentally demanding tasks and challenging conditions that individuals can't cope with. Emotions like anger, shame, and anxiety usually arise from stress, showing a relationship between stress and negative emotions [1, 2]. Additionally, it affects the mind and body in different ways, some of which could relate to cognition, memory, learning, behavior, mood [3], etc.

It has already been studied that users' previous psychological stress conditions at any level are negatively related to their assessment of systems [4]. However, since stress can arise even with the effective use of a product and it can carry over and impact other aspects of life [5], we wanted to study which elements of user interfaces affect user's stress levels while interacting with systems.

This review focuses on stress caused by interacting with digital products and which specific elements of user interfaces could induce stress and result in its known negative consequences. When we say "user interfaces" throughout this paper, we refer to graphical interfaces, specifically websites and mobile applications.

Based on previous studies and literature on the subject, 11 stress-inducing elements associated to 4 different categories (User Experience, Usability, Psychophysiology of Stress and Interface Visual Design) were identified. These referenced studies' scope were limited to only one of the aforementioned categories, specific design elements or specific platforms; while this study merges similar and overlapping concepts to create a complete guide of all elements to take into consideration when designing interfaces in order to avoid causing user stress.

2. Literature Review

Using Google Scholar and searching through keywords like "stress" and "user interface", studies discussing some relation between user interfaces and stress were selected for this review. All selected studies, except one from 1991, were published within the years 2000-2023. However, some of their referenced studies that fall out of this category (published before the 2000s) were also reviewed or included because they were part of the theoretical framework of the selected papers. Most of these cases are studies discussing stress and behavior instead of discussing stress related to user interfaces specifically.

No other relevant studies from 2023 and onwards were found during our search, which further supports the need for a review like the present study.

2.1 Stress & User experience

User interfaces are part of the user experience. User experience design covers the entirety of the user experience while user interface design focuses on the surface and overall feel of a design [6]. Therefore, when designing user interfaces one important element to think about is user experience.

Lim & Suk [7] discussed some user experience aspects of social media network applications that cause stress and its effects on users. They created an online survey, that collected data from 446 social network services (SNS) users, and their results showed that there was a positive relationship between SNS stress and emotional exhaustion, switch intention and resistance.

The media characteristics of SNS combined with social factors could induce stress. For example, the amount of information and self-exposure shared by SNS users creates an environment of social comparison. Also, long-term use of SNS could negatively affect the self-esteem of users as they generally underestimate the impact of negative events in other people's lives, while overestimating positive events, and this causes negative emotions [8].

Dissatisfaction with service stability and low level of attractiveness in functionality and method of use are also reasons for stress and user's switching behavior to more user-friendly alternative services [9, 10].

Emotional exhaustion is the result of psychological stress situations [11] and today's SNS technology requires users to be constantly connected to a service network beyond their limits, which results in psychological overload. If they are not able to cope with the situation, they will experience emotional exhaustion. So, stress is positively related to emotional exhaustion and suspension of use among SNS users [12].

Moreover, when too many perceived risks are associated with using an SNS, it hurts their feelings or violates their freedom; for example, when a new type of system is embedded in an SNS, users may resist using it [13, 14].

In conclusion, elements related to a poor user experience like content overload, service instability, low level of attractiveness in functionality and method compared to other services, too many perceived risks and perceived lack of control or safety could cause stress to users and translate into emotional exhaustion, resistance and switch intention to other services. These findings could be extrapolated to other types of user interfaces besides SNS.

2.2 Stress & Usability

For a good user experience, usability is also important. According to the Nielsen Norman Group, a pioneer in the UX field, usability is the second most important aspect of user experience after utility. Utility only addresses if the product can solve users' problems, but usability measures how well users can use the product to achieve their goals effectively, efficiently and satisfactorily [15]. As mentioned before, emotions like anger, shame, and anxiety usually arise from stress showing a relationship between stress and negative emotions [1]. Because of this, stress is relevant to the study of the relationship between emotions and the usability of an interactive system [16].

Physiological signals like sweat glands activation, heartbeat increases, heartbeat intervals decrease, skin conductance, blood volume, heart rate, eye movement and heart rate show variability during website use [17-20]. Therefore, they can be used to infer emotions and evaluate stress while an user is interacting with a system, and they can help identify usability issues and improve the design of interfaces [16].

Knowing this, De Carolis et al. [16] performed a usability test on the registration to a website. Some users tested a "badly designed" version of the system that violated Nielsen Usability heuristics while the second group tested a "well-designed" version where all usability issues were solved. Participants' stress level was analyzed using a wristband's sensor data collected during the test, after the test they completed the System Usability

Scale (SUS) questionnaire to evaluate the interfaces' usability, and their emotional reactions were captured using the Self-Assessment Manikin (SAM), which assessed valence, arousal, and dominance dimensions.

Higher variation in stress levels was equivalent to lower perceived usability, and direct relationships between the valence and dominance of reported emotional reactions and SUS scores were observed. Additionally, an inverse relationship was found with the standard deviation of stress levels. These results suggest that participants who reported negative emotional reactions and higher arousal were likely to perceive lower usability and exhibit increased variation in stress levels [16].

In conclusion, low usability is related to stress in users, it can be measured through physiological signals, and it could cause negative emotions like anger, shame and anxiety.

2.3 Psychophysiology of Stress

However, these concepts (user experience and usability) don't encapsulate an important side effect of using many products: whether or not it still induces stress. Moraveji & Soesanto [5] studied how stressors can exist despite, or in addition to, usability or user experience issues. Instead of using "user experience" as a guiding principle, they propose the design and evaluation of user interfaces using principles from previous research on stress to mitigate known stressors, particularly the risk of inducing negative psychophysiological state change.

Studies have identified patterns that help predict elements that will likely cause stress and they can be summarized in the following [21]:

- If it feels unpredictable, uncertain or unfamiliar in a negative way [21].
- If it creates the perception of losing or having lost control [22].
- If it could cause harm or loss to the individual's self or associated objects, living things or property [23].
- If it creates the perception of judgment or social evaluative threat including threats to the individual's identity or self-esteem [24].

Based on these stressors' characteristics and through the review of empirical studies they created 10 stress-less design heuristics focused on evaluating stressors in user interfaces and aiming to reduce the probability of an interface containing a known stressor.

Through these heuristics' definitions and considerations, we could identify more detailed stress-inducing elements based on prior studies of stressor characteristics like unpredictability, lack of control, inappropriate tone or emotion, negative feedback, unnecessary time pressures, unsureness, etc. However, the authors point out how their results should be supported with physiological or self-report measures of stress taken during an experiment where these heuristics get applied.

Mullins & Treu [25] also studied the psychological and physiological phenomenon of stress to create a measurement methodology for user satisfaction or dissatisfaction. This is based on the idea that stress, or the lack of it, is an appropriate indicator of users' level of satisfaction or dissatisfaction with a system. From this study we reviewed their research on types of stress and computer-related stress.

Stress could result from a change in expected events or by totally unexpected events and causes a heightening of functions in the autonomic system [26]. Reactions caused by stress include increased heart rate, blood pressure and blood flow to the organs [27].

For computer related stress they discuss how human expectations also play an important role in the interaction with computer interfaces. What users expect or need may differ from what they get, and computer technology tends to increase the required pacing, workload and information-processing demands made on users. These changes lead to stress, especially as people get older [28, 29].

Additionally, researchers like Hart et al. [30] and Sainfort & Lim [31] have studied the effects of factors like task clarity or difficulty and increased mental workload on user stress. Also, if the user can't change the way things are done or control what goals, plans or what kind of feedback they desire, stress will result [32].

Users can be isolated from causes of stress which are external to the interface with careful selection of subjects, an appropriate testing environment, etc. But events at the user interface will affect the user in ways that can be measured. Specifically, dissatisfaction with one or more aspects will cause stress, which could cause the previously discussed physiological reactions. This premise is supported by existing literature on stress in computer-related jobs [25].

In conclusion, changes in users' expectations, task clarity or difficulty, increased mental workload, and lack of control could affect user stress.

2.4 Stress & Interface Visual Design

Poor interface design can cause user stress, lower work rates, decreased job satisfaction and even absenteeism [33]. On the other hand, a good interface design allows operators to complete their tasks effectively, efficiently and with minimal errors [34].

One method used for interface evaluation is based on operators' mental workload (MWL). This technique has become an important measure for evaluation of human computer interface (HCI) in the work environment [35] and it has been demonstrated that the optimization of MWL could reduce human errors, improve system safety, and increase users' satisfaction [36]. As referenced in the previous section, increased MWL affects user stress and satisfaction with an interface is also related to user's stress (or lack of it). So, we can assume that high levels of MWL could directly relate to stress [25], [30, 31].

There are many studies that show that a well-designed interface can provide a suitable operator MWL [37]. We reviewed a study by Yan et al. [38] based on Nuclear Power Plants on the effect of user interface layout on operators' MWL in emergency operating procedures. After analyzing the control circuit in the Chemical and Volume Control system (RCV) based on cognitive psychology principles in layout design, the interface got redesigned and compared to the original interface.

The principles applied were the following [39, 40]:

- Principle 1: Cognition corresponds to objective.
- Principle 2: Task flow design.
- Principle 3: User interface matches users' cognitive strategy.
- Principle 4: User interface in accordance with information organization law.

Participants tested both interfaces in randomized order and performance measurement (time to complete a task and error rate), physiological measurement and subjective ratings were used to evaluate the operators' MWL. They were slower using the original interface rather than the redesigned interface, as they spent less time finishing a task on the redesigned interface, but there was no significant difference in error rate [38]. In theory, if interface design could reduce MWL and enhance situation awareness, error rate would be decreased [41]. However, error rate is often unaffected by workload during short experimental times [42, 43].

There were significant differences in average blink rate, total fixation duration and fixation rate. Compared to the redesigned interface, the average blink rate of the original interface was higher by 14.8%. The operator had to process more visual information in the original interface, so the duration of blinks was lower [38].

Increased eye fixation has been linked to higher MWL [44], and a negative correlation between fixation time and performance has been found [45]. A higher fixation rate on a particular area can indicate greater interest in the target, or it could be a sign that the target is complex and more difficult to search for [46]. In this study there were significant differences between two interfaces in terms of fixation duration and fixation rate, indicating that the redesigned interface is more effective in information searching because it showed lower fixation rate than the original interface.

They concluded that interface layout has a significant effect on MWL because the redesigned interface had lower operators' MWL than the original interface [38]. So, if we design a proper interface layout, we reduce MWL and we can reduce stress, following our initial assumption that high levels of MWL could directly relate to stress.

Another study on the role of color preattentive processing in human–computer interaction task efficiency by Michalski & Grobelny [47] reported results that can help design efficient graphical user computer interfaces in many interactive information systems. The preattentive mechanism constructs metaobjects based on basic features, which work as a guide for human attention during visual search tasks.

The factors considered to invoke the preattentive procedure include color, motion, orientation, pattern or shape of the perceived objects, and this study wanted to find consequences of the color and color pattern as preattentive factors in the search and clicking on the object in the computer graphical interface. Subjects were asked to select a graphical item from a panel containing randomly placed buttons and two dependent variables were recorded: Time and number of errors made. The time was calculated from when the "Start" button was pressed, to when the target graphical object was selected, and it was considered an error when the participant pointed to a different item than the requested item [47].

Their results proved that the color preattentive visual processing is less prominent in visual structures that have a lot of variation in their spatial arrangement, so such arrangements should be avoided, and for higher search and click efficiency we should use higher color contrasts and avoid vertical layouts [47]. These results seem relevant since color preattentive visual processing could help prevent previously mentioned stress-inducing elements like content overload and when the time users take to complete a task feels too long. So, elements that constrain it could cause stress to users.

Additionally, a study researching file icons and spatial grouping on scanning speed by Niemelä & Saarinen [48] showed that both the presence of icons and their grouping had a significant positive effect on the scanning speed. These findings are relevant for an effective arrangement of icons in user interfaces.

To find out if spatial grouping of icons of the same file type increases scanning speed and if icons themselves speed the search rather than textual indicators of the files, participants of their experiment searched for a target file among distractor files in an icon-based computer interface. They studied the effect of grouping by comparing grouped icons and randomly arranged icons, and the role of icons by comparing grouped icons and grouped file names. Search times were faster for grouped icons than for both grouped file names and randomly arranged icons. And the scanning speed was highest for grouped icons and slowest for grouped file names. So, grouping based on both spatial closeness and similar appearance of icons enabled more efficient search than the visual grouping based only on the similarity of icons [48].

3. Results: Stress-Inducing Elements of User Interfaces

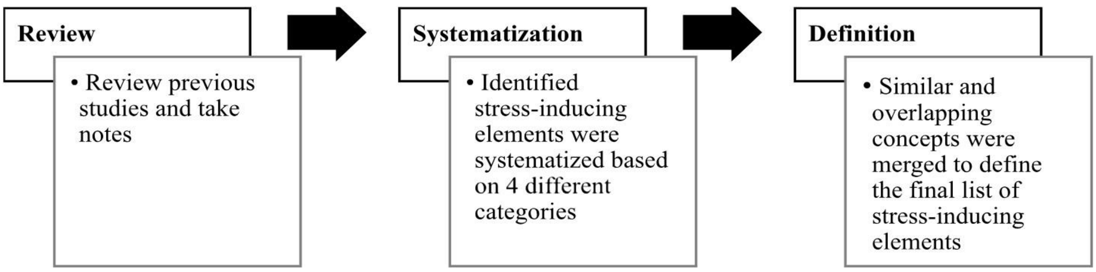
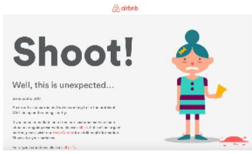
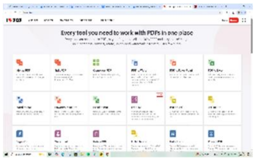
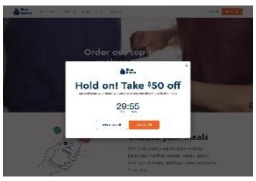


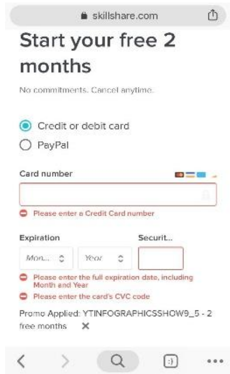
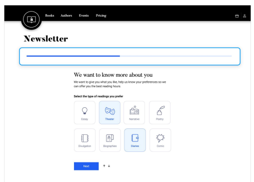
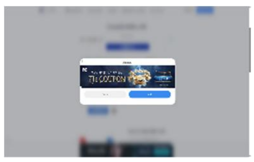
Figure 1. Process graph for identifying the Stress-Inducing Elements of User Interfaces

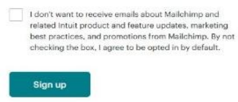
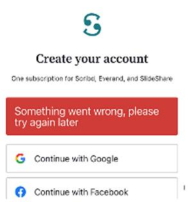
After merging similar and overlapping concepts based on the studied works and complementary research where necessary, this process is shown on Figure 1, a total of 11 stress-inducing elements associated to 4 different categories were identified and systematized in Table 1 along with their definition and examples. Additionally, Table 2 summarizes how all of the previous information was validated by the main referenced authors.

Table 1. Stress-Inducing Elements of User Interfaces

Category	Stress-inducing element	Definition	Example	Sources
User Experience	Content Overload	Excessive amounts of information or perceived duty to be constantly connected to a system beyond the user's limits could result in psychological overload and emotional exhaustion which are related to stress. For example, large sets of data and countless features, options or choices.	 Showcasing an excessive amount of information at the same time.	[7], [12]

User Experience	Service Instability	Dissatisfaction with service stability could cause stress. For example, frequent connection problems.	 Constantly showcasing error state pages.	
User Experience	Low level of Attractiveness	Low attractiveness of functionality or method of use could cause stress. For example, low level of attractiveness when compared to alternative services which are more user-friendly.	  Two different websites for PDF conversion services but the second website is more attractive and user-friendly than the first.	[7], [9, 10]
User Experience, Psychophysiology of stress	Lack of Control	The perception of losing or having lost control when interacting with a system, or having no control over their preferences and settings within a system, could cause stress. For example, large sets of data and countless features, options or choices (also related to Content Overload) could make users feel overwhelmed and feel a lack of control over the amount of information or time required for using the system. Also, the lack of control over when one can use the system. Pressure for time from the system could also cause users to feel a lack of control. And lastly, if the user can't change the way things are done or	 Applying time pressure for users to take an action.	[7], [13, 14], [22], [32]

		control what goals, plans or what kind of feedback they desire (flexibility of use, also related to Usability), stress could result.		
User Experience, Psychophysiology of stress	Low level of Safety	Too many perceived risks or the possibility of causing harm or loss to the user's self or related objects, living things or property associated with using a system could cause stress. For example, when a new type of embedded system hurts user's feelings or violates their freedom, or when there are countless choices (also related to Content Overload and Lack of Control) users may feel unsure of the results of their actions and asking for help could threaten their self-esteem.	 Services that request for user's payment information before starting a free trial could lead to users forgetting to cancel the subscription and losing money.	[5], [7], [13, 14], [23]
Usability	Low Usability	Low usability "badly designed" systems that violate the Nielsen Usability Heuristics could cause negative emotions like anger, shame and anxiety which are related to stress.	 A loading bar with no percentage or steps counter violates the heuristic of "Visibility of System status".	[1], [16]
Psychophysiology of stress	Unpredictability	Unpredictable features, inconsistencies or interruptions when using a system could cause stress. For example, unpredictability over when they can use the system and unpredictable interruptions that affect the control users have on their own focus (also related to Lack of Control). Also, when users	 Pop-up ads right after clicking a button to perform an action on a website (unpredictable interruption).	[5], [21], [25, 26], [28-31]

		expect to take an action that is not available (change in expected events) or totally unexpected events.		
Psychophysiology of stress	Uncertainty	Inconsistencies across a system's elements and interactions or lack of clarity about users' actions and their results could cause stress. For example, inconsistent interactions, elements, layout or when there are countless choices that may make users feel unsure of the results of their actions (also related to Content Overload and Lack of Control). Additionally, low task clarity or high task difficulty and increased mental workload could affect stress.	 Adding a checkbox to a negative action is unclear and misleading.	
Psychophysiology of stress	Unfamiliarity	Failing to maintain consistency across a system could increase the users' cognitive load by forcing them to learn something new continuously and cause stress. For example, inconsistent interactions, elements or layout across a system (also related to Unpredictability and Uncertainty).	 There are inconsistent elements and layout.	
Psychophysiology of stress	Judgment or social evaluation threat	Features or interactions of a system that could result in the users' perception of being judged or evaluated could cause stress. For example, users' self-identity is threatened by content overload because they may feel they aren't engaging enough with the system, have not added sufficient input or aren't keeping up with other users. Also, negative feedback like	 Negative feedback that doesn't notify the user about the reason for the error or how to fix it.	[5], [24], [49]

		invalid input, unavailable features, etc.; violate expected norms of conversational interaction and could cause stress by threatening users' self-esteem or causing the feeling that they can't provide the machine with the information it needs. Lastly, pressure for time from the system could also cause users to worry about how they appear in a competitive sense if the time they took to complete a task feels too long.		
Interface Visual Design	Poor Visual Design	Interface layout, proper visual indicators, color contrast and grouping of objects have a significant effect on mental workload and performance so a poor visual design could cause stress. For example, we discussed previously how it affects users if the time they take to complete a task feels too long so a layout that triggers a slow performance could cause stress. The presence of icons and spatial grouping of elements speeds the search of a target, so the lack of them or complex/inconsistent spatial arrangements could cause stress to users. Lastly, to ensure higher search and click efficiency higher color contrasts and avoiding vertical layouts is recommended.	 There is a poor color contrast between the text and background, and it uses the same visual indicator for all menu options making them hard to distinguish.	[38], [47, 48]

Table 2. Validation methods of the main referenced studies

Category	Study	Validation method
User experience	Lim & Suk [7]	Online survey
Usability	De Carolis et al. [16]	Usability test
Psychophysiology of Stress	Moraveji & Soesanto [5]	Literature and empirical studies review
	Mullins & Treu [25]	Literature review
Interface Visual Design	Yan et al. [38]	User testing
	Michalski & Grobelny [47]	Experiment
	Niemelä & Saarinen [48]	Experiment

4. Discussion

With this study we wanted to identify which specific elements of user interfaces could induce stress to users while interacting with digital products, specifically graphical interfaces like websites and mobile applications, and result in its known negative consequences. To do so, previous studies discussing some relation between user interfaces and stress were selected and reviewed. After merging similar and overlapping concepts 11 stress-inducing elements were identified: Content Overload, Service Instability, Low level of Attractiveness, Lack of Control, Low level of Safety, Low Usability, Unpredictability, Uncertainty, Unfamiliarity, Judgment or social evaluation threat and Poor Visual Design.

While the referenced studies discussed stress related to only one specific field like user experience [7], usability [16], psychophysiology [5], [25] or visual design [38], [47, 48]; were limited to only one specified design element like layout [38], color [47] or icons [48]; or were limited to specific platforms like SNS [7] or Nuclear Power Plants' system interface [38], our study had a more holistic approach that identified and defined a wider variety of elements related to 4 different categories (User Experience, Usability, Psychophysiology of Stress and Interface Visual Design) and that could be applied to various types of user interfaces.

Also, some of these studies don't mention a direct relation between their findings and stress but to elements directly related to stress like mental workload, time spent to complete a task, etc. By examining and integrating different sources, this study identifies a relation between their findings and stress.

We believe the present review contributes to the literature on user interface by providing a set of elements to avoid for designing better interfaces that take into consideration users' mental and emotional state. Design guidelines or heuristics could be derived from these identified elements, after validated through further empirical research, to help design better interfaces while taking into consideration users' mental and emotional state.

5. Conclusion

Different elements related to various factors of user interfaces, or related to the psychosociology of stress itself, can cause stress on users while interacting with a product or system and 11 specific elements associated to 4 different categories were identified; all of which evoke negative emotions that could be related to stress on users. Since stress can arise even with the effective use of a digital product, this set of elements could help us design better interfaces while taking into consideration users' mental and emotional state.

However, there are some limitations to this study. First, only several journal articles were reviewed, and they weren't narrowed down to a specific field of study. Additionally, no further empirical research was conducted.

As discussed on this review, physiological signals like sweat glands activation, heart rate (heartbeats), skin conductance, blood volume, blood pressure, eye movement, heart rate; and blink rate or eye fixation, fluctuate during our interactions with a system and can be used to measure stress. This information is relevant as for future research the validity of these proposed stress-inducing elements, that are just supported theoretically, could be evaluated through an experiment tracking these signals. For example, a comparative experiment of two websites, one that applies these stress-inducing elements and one that eliminates them, where we track users' physiological signals to determine the variability in stress levels while interacting with both systems.

Acknowledgments: This research was supported by the MSIT (Ministry of Science and ICT), Korea, under the ITRC (Information Technology Research Center) support program (IITP-2021-0-02051) supervised by the IITP (Institute for Information & Communications Technology Planning & Evaluation), the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2023S1A5C2A02095195), and Ajou University Research Fund (S-2023-G0001-00423).

Conflicts of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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