Cognitive Feedback Theories and Artificial Intelligence: A Case for A Grammarly of UI/UX Design

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Cognitive Feedback Theories and Artificial Intelligence:

A Case for A Grammarly of UI/UX Design

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Abstract

This thesis is concerned with utilizing artificial intelligence and machine learning (AI/ML) techniques and cognitive theories of feedback to enhance learning outcomes in the field of user interface and user experience (UI/UX) design. The capabilities of AI/ML have expanded immensely over the past several years, and it is now being effectively used in software programs like Grammarly, a tool that provides intelligent feedback on writing skills including grammar, tone, and clarity. Grammarly has been uniquely successful as a feedback tool because it relies on lessons from cognitive science regarding student feedback and learning outcomes. Currently, there is no comparable software available for UI/UX, making it a uniquely untapped area for effective learning tools. The question that this thesis attempts to answer, therefore, is: **How can the successes of Grammarly and established cognitive feedback principles inform the design of an AI/ML-based feedback tool for UI/UX design?** To answer that question, this thesis explores previous work on AI/ML techniques, cognitive feedback theories, structural similarities between grammar and design, and design heuristics in order to ultimately define the theoretical groundwork for a “Grammarly for UI/UX design.”
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I. Introduction
Introduction

The field of artificial intelligence (AI) and machine learning (ML) has rapidly expanded over the past several years, offering more advanced capabilities than ever before. Some fields have been highly successful at harnessing those developments. For example, Grammarly, an automated writing feedback software that provides feedback to users on grammar, tone, and clarity among other writing skills, has been exceptionally successful as an effective tool for teaching users how to write better. Part of the reason that it is so effective is that it makes excellent use of cognitive feedback principles, utilizing what we know about how our brains best receive and implement feedback. However, one field where a teaching AI tool has not yet been implemented is user interface and user experience (UI/UX) design. Many plugins have been developed for UI/UX design software to help designers fix problems in the apps and websites that they are prototyping, but none of them target teaching the user how to become a better designer in a more holistic sense. The goal of this thesis is therefore to draw a connection between the structure of grammar and UI/UX and to provide the theoretical framework for a “Grammarly of UI/UX design” which could be advantageous for designers not only by improving their designs but also by helping them actually learn and improve over time.

This thesis is broken into a series of chapters to provide the necessary background and argue the case for a Grammarly for UI/UX design. The first chapter introduces important previous research that has been conducted in several relevant fields. It begins with a discussion of the history of artificial intelligence including an overarching explanation of what it is and its functionalities and a more specific explanation of its role in educational contexts which is significant to the concept being proposed here. Following the section on the foundations of artificial intelligence is a thorough examination of relevant cognitive theories of feedback.
Several interrelated theories are discussed including Lipnevich and Panadero's Model of Feedback Elements: the MISCA (Message, Implementation, Student, Context, and Agents) and three types of corrective feedback: direct, indirect, meta-linguistic. Following that is a section on Grammarly which provides background on Grammarly’s purpose and function. Moreover, that segment dives into academic research on Grammarly to explain ways that it has been effective and ineffective, and how it employs the cognitive feedback theories previously examined. Following that is a section on the foundations of UI/UX design and heuristics. That part describes the significance of UI/UX design in the modern day, how it is implemented, and what makes it better or worse based on the established heuristics of design. The final component of the previous work chapter is how UI/UX design software plugins can help and hurt. As previously mentioned, many plugins have been developed to help designers work more efficiently and effectively in UI/UX prototyping software, and while those plugins are often very useful they can also hinder users.

The next chapter is entitled UI/UX Design and Grammar and focuses on establishing the relationship between UI/UX design and grammar and how they are structurally similar. It is broken into two subsections, the first focusing on “a grammar of design” which is the concept that design follows rules and concepts that are similar to those in writing. It also explores how learning UI/UX design and grammar might be cognitively similar processes. The next subsection of that chapter provides an argument for the need for some sort of Grammarly for UI/UX design based on the interrelatedness of the subjects and the gap that currently exists in UI/UX plugins.

The next chapter is the bulk of the thesis and provides a thorough exploration of the concept of a Grammarly for design that is being proposed. The first subsection provides a short overview of what the plugin would look like in a holistic sense. It then turns to the next
subsection which focuses on why this type of plugin would matter. Following that is a description of how it might work in a technical sense including the AI/ML techniques that would be implemented. Next is a discussion of the design heuristics that would be targeted in the proposed plugin. The next subsection provides the last part on how the plugin should work with a proposal for how the feedback should be delivered to users based on the cognitive feedback principles and successes of Grammarly described in the previous work chapter. The next section describes why this plugin ought to work, and the final part discusses future work that should be done to further develop the plugin.

The last chapter of the main body of the thesis is the conclusion which provides some closing thoughts. It is followed by a works cited section and a supplementary materials section with some examples of what the plugin might look like in action. As a whole, the hope is that this thesis probes readers to envision not only what the plugin being proposed might look like, but also to think more critically about how we can use the exceptional capabilities of AI/ML to lead to real learning.
II. Previous Work
1. **Foundations of Artificial Intelligence**

The field of Artificial Intelligence (AI) originated in the 1950s and 1960s when computer scientists began exploring the notion of building machines that could perform tasks that would otherwise require human intelligence (Kühl et al., 2022). In the years since then, AI has taken off as a highly complex and interdisciplinary field that incorporates research from cognitive science, computer science, philosophy, and other domains. The broad concept of AI is that by mimicking human cognition, machines can carry out human-like assignments. Within the overarching field of AI, Machine Learning (ML) specifically involves using algorithms and statistical models to enable machines to improve their performance on particular tasks. Those models train on massive sets of data and continuously increase their accuracy based on feedback. The goal of AI/ML is to improve that accuracy to the extent that those machines can carry out jobs that would otherwise require a human mind, such as recognizing patterns, making decisions, and learning from experience (Kühl et al., 2022). Operating with speed and accuracy, AI accomplishes tasks that humans do far more slowly and with inferior precision, constituting it as powerful and ripe with potential. Early applications of AI were rather rudimentary, with programs carrying out tasks such as solving math problems given a set of rules or playing chess against a real person. The field has since made remarkable progress, and AI/ML is now integrated into many aspects of our lives. From sophisticated voice assistants to self-driving cars to advanced medical diagnosis and treatment, AI is changing the way we live, work, and interact with the world around us.

Due to its powerful nature, AI is increasingly being used in educational contexts to provide feedback to students (Chen et al., 2022). AI-powered systems can analyze student work, providing feedback that is more accurate, efficient, and personalized than traditional methods.
For example, AI can assess written essays, providing feedback on grammar, style, and content. By providing student-specific writing feedback, AI systems can help students identify their strengths and weaknesses, aiding in their overall learning progression (Woodworth & Barkaoui, 2020). Moreover, AI can analyze the student’s learning styles to cater to their particular levels of motivation and engagement which is critical to their educational success. Overall, AI is playing an increasingly important role in providing feedback in educational contexts, helping to create a more efficient, effective, and personalized learning experience for students.

Although AI has the potential to revolutionize the way education is delivered, it is not without its drawbacks. One of the main limitations of using AI in an educational context is that it tends to automate processes rather than push students to learn (Koltovskaia, 2020). By relying on AI systems to provide feedback, students may not be challenged to think critically or cognitively engage with the material in a meaningful way. Rather than encouraging students to actively seek knowledge and develop their skills, AI systems can create a passive learning experience that fails to promote deeper understanding or retention of information (Ranalli, 2021). This limitation is a significant concern, as education should not just be about acquiring knowledge, but also about fostering critical thinking, problem-solving, and creativity. As a result, the use of AI in education must be balanced with a focus on student-centered approaches that promote active engagement and self-directed learning. This will help to ensure that students receive the benefits of AI while also being challenged to develop the skills and habits of mind that will serve them well throughout their lives. To that end, cognitive science can help provide significant theoretical groundwork for designing feedback tools.

2. Cognitive Theories of Feedback
Many cognitive scientists have worked towards the goal of understanding feedback and how to provide it in a manner that is more effective for students. Before considering how to deliver it, though, it is important to first grasp what feedback is. Academics have proposed assorted definitions, but the paper “A Review of Feedback Models and Theories: Descriptions, Definitions, and Conclusions” sums it up nicely: “Feedback is information that includes all or several components: students’ current state, information about where they are, where they are headed and how to get there, and can be presented by different agents (i.e., peer, teacher, self, task itself, computer). This information is expected to have a stronger effect on performance and learning if it encourages students to engage in active processing” (Lipnevich & Panadero, 2021). The authors distilled that definition from a review of fourteen prominent models and theories of feedback, all of which have received considerable attention.

Lipnevich and Panadero continue their work in the follow-up article “A review of feedback models and typologies: Towards an integrative model of feedback elements” in which they propose their Integrative Model of Feedback Elements: the MISCA (Message, Implementation, Student, Context, and Agents), a comprehensive framework for understanding feedback in education which incorporates many different theories and approaches (Panadero & Lipnevich, 2022). The model provides a useful framework for understanding the complex interplay between the different elements of feedback and highlights the importance of considering all of these elements when designing feedback strategies in education. Because it distills the most prominent cognitive feedback approaches, MISCA will be used as a central theory for this thesis. An overview of the model is provided in Figure 1, showing the four key components with the student at the core (Panadero & Lipnevich, 2022).
**Figure 1:** MISCA model of feedback elements as proposed by Lipnevich and Panadero.

The entire model is centered around the learner to reflect a shift in literature towards focusing on agentic use, uptake of feedback, and feedback receptivity as key components of understanding feedback (Panadero & Lipnevich, 2022). A range of characteristics can have important implications on what type of feedback is best received including motivational beliefs, prior knowledge, gender, cultural differences, self-efficacy, and personality traits which is why understanding the individual at the center is so consequential to this feedback theory (Lipnevich et al., 2016). Feedback only matters if the student ultimately receives and grows from it, and the structure of the model reflects that goal.

The four pieces of the MISCA model which surround the student are **message**, **implementation**, **context**, and **agents** (Panadero & Lipnevich, 2022). A strong **message** should
answer three questions: “(1) Where is the student going? (goals, feed up); (2) How is the student going? (current state, feedback); and (3) Where to next? (closing the gap, feed forward)” (Panadero & Lipnevich, 2022). In doing so, a clear message will help the student to understand how exactly they are performing at present as compared to their goal which will inspire agentic use. The implementation component highlights the importance of considering the instructional and learning purposes when implementing feedback in education. Moreover, this piece of the puzzle integrates function and internal processing, meaning that both the goal of the feedback and the potential cognitive processing of said feedback are relevant to its design. Meanwhile, the instructional context piece serves as a reminder that reaching students in the right condition is paramount to feedback uptake. Timing and delivery mode are both highlighted in this category as key considerations for providing effective feedback. Finally, agents are discussed as the fourth component, encompassing the teacher, peers, learner, and in some cases the technology. Self and peer assessments can be just as formative as instructor feedback, so integrating them is important in understanding a theory of feedback more broadly.

Another helpful way to understand effective feedback is with the groundwork of corrective feedback (CF) which refers to any information given to learners regarding their performance, to help them correct any mistakes or errors they have made. There are different types of corrective feedback, which can be classified as direct, indirect, and meta-linguistic feedback (Caras, 2019).

1. Direct Feedback: This type of corrective feedback is given immediately after the error has been made. It involves explicitly correcting the error in a timely manner by providing the correct form or structure. For example, a teacher might correct a student's grammar mistake by providing the correct sentence structure (Caras, 2019).
2. Indirect Feedback: This type of corrective feedback is given after the error has been made, but without providing the correct form or structure. Instead, the learner is given a hint or a clue about what the correct form should be. For example, a teacher might ask a student to repeat a sentence or rephrase a sentence using a different word (Caras, 2019).

3. Meta-Linguistic Feedback: This type of corrective feedback focuses on the language used to communicate, rather than the content of the message. It involves providing information about the language itself, such as grammar rules or vocabulary usage. Meta-linguistic feedback can be provided through explicit instruction or implicit correction. For example, a teacher might explain a grammar rule to a student, or they might correct a student's pronunciation without explicitly pointing out the error (Caras, 2019).

Studies have demonstrated that corrective feedback is helpful to students, with different results on which type of CF (direct, indirect, meta-linguistic) is most effective (Caras, 2019; Eslami, 2014; Bitchener, 2008). These mixed findings provide support for offering varied forms of CF to students.

3. Grammarly

One product that has proven particularly effective at incorporating leading feedback models with AI advancements is Grammarly, a widely used automated feedback software that utilizes AI and ML to provide students feedback on their writing (Grammarly, 2019). Grammarly's AI system scans the text and provides feedback in real-time, highlighting potential errors and suggesting alternative phrasing and corrections. By doing so, it helps students understand why certain mistakes were made and how to avoid making similar mistakes in the future. This allows students to develop their writing skills in a more holistic way where most grammar checkers provide the solution without additional context to promote real learning.
The software uses advanced algorithms to analyze the writing of students with a free basic version and paid premium version. The premium version, which is the version referred to for this thesis, provides corrections across eleven variables: spelling, grammar, punctuation, conciseness, clarity-focused sentence rewrites, tone adjustments, plagiarism detection, word choice, formality level, fluency, and additional advanced suggestions (Grammarly). Some examples of these corrections as shown on Grammarly’s website are depicted in Figure 2 (Grammarly). Grammarly also provides an expanded version of the feedback along with additional examples to explain to the student why the correction is being suggested in greater depth. The student is given the option to accept or decline the suggested fix. Grammarly then tallies the number of corrections across each type of correction and provides that information to the student so that they can understand their writing strengths and weaknesses holistically and track their overall progress over time.

**Figure 2: Examples of the type of feedback that Grammarly Premium provides to users** (Grammarly).
Grammarly has been the subject of a series of academic papers which have discussed its effectiveness in educational contexts, many of which highlight the immediacy and specificity of feedback that Grammarly provides. A large portion of those studies focus on student perception, generally finding that students typically appreciate the type of feedback and structure provided by Grammarly (Fahmi & Cahyono, 2021); (O’Neill & Russell, 2019); (Fitriana & Nurazni, 2022); (Qassemzadeh & Soleimani, 2016); (Reis & Huijser, 2016); (Cavaleri & Dianati, 2016). For example, the article “The Effectiveness of Using Grammarly to Improve Students’ Writing Skills” found that students who used Grammarly were more confident in their writing abilities and felt that the software helped them to become better writers (Huang et al., 2020).

Additionally, the Huang et al. (2020) paper and others have found that students not only believe that Grammarly helps them become better writers, it actually does (Japos, 2022); (Ghufron & Rosyida, 2018). The study “The Impact of Feedback Provision by Grammarly Software and Teachers on Learning Passive Structures by Iranian EFL Learners” investigated the impact of feedback provided by Grammarly software and teachers on Iranian EFL (English as a Foreign Language) learners’ understanding and use of passive structures in writing (Qassemzadeh & Soleimani, 2016). The study reported that students who received feedback from Grammarly made significant gains in their use of passive structures compared to the control group in post-tests (Qassemzadeh & Soleimani, 2016). Those findings suggest that the manner in which Grammarly provides feedback may be more effective than that given by teachers in certain cases which suggests that AI-based feedback tools can play a key role in education when implemented correctly, a conclusion that has been replicated by other studies (Japos, 2022); (Ghufron & Rosyida, 2018). Importantly, many of the studies discussing the effectiveness of Grammarly relate its successes to cognitive theories of feedback, particularly CF. O’Neill and
Russell (2019) are particularly effective at explaining how Grammarly utilizes a combination of direct, indirect, and meta-linguistic feedback. They describe how providing all three types of CF allows for more holistic and effective learning. The study “Student engagement with automated written corrective feedback (AWCF) provided by Grammarly: A multiple case study” provides a similar analysis, describing how Grammarly makes use of the cognitive underpinnings of CF (Koltovskaia, 2020).

Despite the praise that Grammarly has received from many academics, others have raised the issue that students can become over-reliant on the feedback that the program provides, resulting in a lack of cognitive engagement and inferior learning outcomes. For example, the paper “Grammarly: Help or hindrance? Academic Learning Advisors’ perceptions of an online grammar checker” provides a nuanced view on the matter, finding that while AI-powered tools like Grammarly can provide helpful feedback to students, they can also impede the development of writing skills if used inappropriately (O’Neill & Russell, 2019). Specifically, one participant noted that “students may become too reliant on Grammarly and neglect to learn the rules of grammar, which could negatively impact their future writing ability” (p. 8). Because Grammarly is a relatively new tool with constantly improving feedback, there is no conclusive and longitudinal evidence to support the claim that it inhibits learning. Nonetheless, there is a fine line between AI-based tools that are helpful to learning and those that allow students to cognitively disengage in the process, and the mixed perspectives that have been published on Grammarly suggest that it falls right on the edge.

4. Foundations of UI/UX Design and Heuristics

User interface (UI) and user experience (UX) design are two distinct but interrelated components of digital design that are concerned with providing the best encounter with a digital
interface both visually and experientially. UI design focuses on the visual layout and interactive elements of a product or service such as buttons, menus, and icons. It involves creating a visual language that is consistent with a brand’s identity and designing elements that are intuitive and easy to use for the user. UX design, on the other hand, focuses on the overall experience that the user has while interacting with a product or service. It involves understanding the user’s needs, goals, and behaviors and designing a product or service that meets those needs most efficiently and enjoyably. Both UI and UX design are critical to the success of a digital product or service, and learning how to create excellent UI/UX design as a design student is paramount.

There is a large body of work describing what exactly designates UI/UX design as “good.” These factors are referred to as design heuristics and act as general rules of thumb that all strong designers incorporate into their work. Many have proposed assorted principles including Gestalt principles, Don Norman’s seven principles of design, Nielsen’s Heuristics, and other more general heuristics.

Gestalt principles, also known as the laws of perceptual organization, are a set of principles that describe how humans perceive and organize visual information (Todorovic, 2008). These principles were developed by psychologists in the early 20th century, and they continue to be relevant in cognitive science, design, and user experience. They are important for designers and other visual communicators to keep in mind when creating visual materials, as they can help to create more effective and engaging designs that are easier for people to understand and remember.

The following are some of the key Gestalt principles (Todorovic, 2008):

1. The Principle of Figure-Ground: Humans tend to perceive objects as either the foreground (figure) or the background (ground).
2. The Principle of Proximity: Objects that are close to each other tend to be perceived as a group.

3. The Principle of Similarity: Objects that are similar in appearance tend to be perceived as a group.

4. The Principle of Continuity: Humans tend to perceive objects as continuous shapes, even if they are interrupted by other objects.

5. The Principle of Closure: Humans tend to perceive incomplete figures as complete by filling in the gaps.

6. The Principle of Common Fate: Objects moving in the same direction are related.

7. The Principle of Past Experience: Our prior experiences impact the way we take in visual information.

Don Norman’s seven principles of design, meanwhile, apply more directly to UI/UX design than design broadly and focus on making pages delightful and effective (Dillon, 2020). They are not as concrete as Gestalt principles but instead, refer to the overall user interactions with a given design.

The following are Norman’s principles of design (Dillon, 2020):

1. Discoverability: The options for what can be done on a current page or state should be visible to the user.

2. Feedback: Users should be able to immediately see what the effect of their action on a page is.

3. Conceptual models: People hold mental representations of the page they are interacting with.

4. Affordance: Perceived and real properties of a given object.
5. Signifiers: Markers for how to use the page.

6. Mapping: Link between the controls and their results.

7. Constraints: Designer-created restrictions on what can occur.

   Similarly, Jakob Nielsen proposed design heuristics which are commonly referred to by
   designers that emphasize UI and usability (Aela, 2022) (Nielsen, 2020). He lays out ten
   principles that are intended to make design more accessible and user-friendly to view and engage
   with. Some of them thematically overlap with Norman’s list, but as a whole set, they provide a
   distinct framework (Nielsen, 2020).

   These are Nielsen’s principles (Nielsen, 2020):

   1. Visibility of system status: A user should be able to see the state of the page and how
      their interaction impacts that state.

   2. Match between the system and the real world: The phrases and layout of a page should
      match what the user is familiar with from the real world.

   3. User control and freedom: Users should be able to undo or escape their past actions.

   4. Consistency and standards: The same wording and design should be used across a site.

   5. Error prevention: Designs should help guide users away from potential mistakes.

   6. Recognition rather than recall: Decrease cognitive load by keeping information visible.

   7. Flexibility and efficiency of use: Allow shortcuts for more advanced users.

   8. Aesthetic and minimalist design: Avoid unnecessary information, and stick to the
      essentials instead to create a clean design.

   9. Help users recognize, diagnose, and recover from errors: Create clear error messages and
      states.

Another set of design principles that has more recently become important in the world of design is the Universal Design principles which are intended to encompass accessibility, inclusivity, and usability (The 7 Principles: Centre for Excellence in Universal Design, n.d.). The focus of these principles is to make design available to all people regardless of disability, age, or other factors which might impact their ability to interact with certain designs.

The Universal Design principles are as follows (The 7 Principles: Centre for Excellence in Universal Design, n.d.):

1. Equitable Use: The design can be used by people with various disabilities and identities.
2. Flexibility in Use: The design takes into consideration personal preferences and allows for those differences.
3. Simple and Intuitive Use: The user’s previous experience is not a barrier to understanding the design.
4. Perceptible Information: Ambient conditions and sensory abilities do not negatively impact the use of the design.
5. Tolerance for Error: Potential accidents are limited.
6. Low Physical Effort: Using the design is efficient and avoids a high cognitive load.
7. Size and Space for Approach and Use: The sizing and spacing of the design are suitable for the goal and content.

All of these design principles intersect at different points and together provide an important foundation for UI/UX designers to keep in mind when working. There are certainly cases of good design that do not perfectly encompass all of these guidelines, but they nonetheless act as helpful pillars of design.

3. How Design Plugins Can Help and Hurt
UI/UX design software systems allow designers to create and test designs of websites and apps without writing any code. Common programs such as Adobe XD, Figma, and Sketch, include drag-and-drop interface building, wireframing, prototyping, and user testing. They also allow users to add plugins which are additional tools or features that can enhance or append capabilities. These plugins can help designers streamline their workflow and create more engaging, user-friendly designs, but they can also hinder the design learning process by providing easy fixes without instilling any true knowledge. There is a massive breadth of plugins from those that help designers with accessibility issues like color contrast and font size to those that provide image libraries. The emphasis of many of those plugins is to speed up the design process, helping designers cut out unnecessary and time-consuming steps (Zhang, 2022). For example, the Figma plugin UIHUT allows designers to view and copy templates and design kits which is helpful for experienced designers seeking to move quickly and cut out redundant work (Samala, 2022).

However, cognitive research on learning strategies suggests that practicing those basic steps, even if labor-intensive and slow, is what helps people actually learn a new process (Weidman & Baker, 2015). At present, corrective plugins (such as those that target spelling errors or accessibility issues for users with color vision deficiencies) are very effective at solving the problem quickly. However, because most plugins focus on one highly specific subject and designers have to seek out and download that particular plugin, their structure rightfully assumes that the designer already understands the premise of the issue that they are solving. Therefore, the plugins do not explain the problem in any depth or probe for deeper learning in the designer. This mechanism is effective for experienced designers but poses a challenge to designers who
are just getting started and might not yet have the background to understand why something is an issue, how to fix it, and how to avoid the mistake moving forward.
III. UI/UX Design and Grammar

Despite the numerous differences between UI/UX design and grammar as forms of conveying information, they have key similarities in their construction which allows people to learn and understand them in comparable manners. Some, including myself, would posit that there is a “grammar of design” (Glass, 2020). Grammar is the structural system that provides the scaffolding for us to understand written and spoken language. If language were visual, UI/UX would act as that same scaffolding to help translate it into something more easily understood by people. Both grammar and UI/UX rely on a set of heuristics or best practices to be most digestible. For example, take the sentences “I the dog pet” and “I pet the dog.” One might be able to deduce the correct meaning from the first sentence, but the latter is far more intuitive because it adheres to accepted rules of English grammar (Glass, 2020). Similarly, if you were attempting to submit a form online and after filling out all required fields you were presented with the second button shown in Figure 3, you would ultimately intuit that you could press the button to submit it, but the first button would be more obvious (Babich, 2022). That is because in design there is a widely accepted rule of thumb that a grayed-out button means that it is disabled.

![Submit Button](image)

![Submit Button](image)

**Figure 3:** Enabled versus disabled button in a user interface (Babich, 2022).

The example of the button is one of many which demonstrate that UI/UX and grammar design are similar because they rely on heuristics. In the same way that grammar heuristics like concision, clarity, and tone help readers understand your point effectively and quickly, design
heuristics like visual hierarchies, color contrast, and white space help users accomplish what they need to do (Visual Grammar - UX Design Strategy for Component-Based Systems, n.d.). Though language can be understood to a certain extent without the structural confines of grammar, and design can be deciphered without the framework of UI/UX principles, both grammar and UI/UX underlie the cognitive information that the relevant medium is attempting to convey in a way that is paramount to the ease of interpretation.

In linking the distinct concepts of grammar and UI/UX, it is important to explain how the heuristics of each are interrelated. Grammatical rules can be split up into prescriptive and descriptive grammar. Prescriptive rules relate to how a language “should” be spoken and include concepts such as “don’t end a sentence with a preposition” which was proposed by John Dryden who said English should follow that rule simply because Latin does. Descriptive grammar, meanwhile, is more focused on the rules that act in accordance with how native speakers actually use the language. Those heuristics are what matter most in the leap from language grammar to UI/UX. Design is more concerned with descriptive over prescriptive rules. There is no governing body dictating that a button must not be grayed out if it is enabled, but that is a generally accepted rule in conformity with our daily usage of design.

Beyond the similarities in their descriptive heuristics, grammar and UI/UX share certain commonalities in how we come to acquire those rules. There are two conflicting stances on language (and grammar) acquisition: the nativist/rationalist perspective and the empiricist perspective (Barman, 2012). The nativist perspective, raised by Noam Chomsky, supports the notion of a universal grammar which means that there is something innate about our understanding of language that is built in when we are born (Chomsky, 2002). The empiricist perspective, championed by B.F. Skinner, claims that reinforcement learning is a better learning
model and that we can think of acquisition as being rewarded for imitation which eventually leads to a holistic understanding (Skinner, 1957). There are critiques to each theory, but to maintain the scope of this thesis, they will not be explored at length. Moveover, though both nativism and empiricism have their own merits, empiricism is more relevant in the context of UI/UX because it is easier to imagine how one might come to learn design through reinforcement rather than a universal design grammar, so empiricism will be used as the dominant theory in this thesis.

Using the framework of empiricism, we can understand how grammar and UI/UX can be learned in similar ways. In the same way that a parent might correct a child who incorrectly says “I the dog pet” to reinforce proper grammatical structure, our understanding of UI/UX is reinforced every time we interact with a design. For example, if you failed to complete all required fields in a form and tried to click the gray disabled submit button shown in Figure 3, nothing would happen and the form would not submit. This outcome would reinforce your understanding of that UI/UX heuristic, and you would know moving forward that if a button looks like that it is probably disabled for some reason.

2. Identifying The Need

As has been demonstrated, grammar and UI/UX share commonalities both in their structure and how they are learned. However, one key difference between the two is that there are mechanisms like Grammarly that have been created to help people improve their written grammar. Grammarly helps users at all stages of learning to work on a wide range of grammar heuristics, providing helpful insights to inspire real learning rather than easy fixes. Though there are plugins that you can add to UI/UX software to target specific issues as previously discussed, none emphasize holistic teaching in the same way that Grammarly does. Moreover, while new
designers might have an intuitive understanding of UI/UX heuristics from interacting with good design in their day-to-day lives, they often do not know how to put those into practice when actually creating an app or website. Therefore, having a tool that helps students learn about the UI/UX flaws in their design and how to fix them is a key gap in current UI/UX plugins.
IV. A Grammarly for Design
1. Overview

Based on the need that has been identified, this thesis proposes a new UI/UX design teaching plugin that operates as a “Grammarly for design.” The concept is a plugin that uses AI/ML to identify UI/UX design flaws in a design created in Figma or Adobe XD. It would address a larger series of heuristics than current single-focused plugins do, as will be discussed later. Moreover, it will constructively provide feedback, incorporating lessons from cognitive feedback principles and Grammarly’s successes.

2. Why it Matters

This plugin would prove useful and important for designers who are interested in learning how to make more creative and original outputs. One could certainly make the argument that given the current direction of AI capabilities, learning how to design well is going to quickly become obsolete. Generative AI has become increasingly advanced, and products such as Galileo AI, Looka, and Uizard are all able to create original UI through assorted AI techniques (Galileo AI: Copilot for Interface Design, n.d.; “How to Create a Logo With Looka Logo Maker,” n.d.; Uizard | App, Web, & UI Design Made Easy | Powered By AI, n.d.). Galileo AI is a product trained on thousands of strong designs which can convert natural language prompts into original UI designs. Looka generates logos and web interfaces using AI based on a brand name and the design preferences that you input. Meanwhile, Uizard uses AI to convert screenshots or sketches into interactive UI designs. While all of those are great products for someone looking to move quickly and generate a design that will work well enough, they do not foster creativity or original thinking. To create something new and exciting, designers need to learn the basic heuristics that act as scaffolding for beautiful and radically usable design. Therefore, while those products are incredibly helpful for a certain subset of users, another subset who is eager to push the
boundaries of excellence and accessibility in design could be better suited to a product that uses AI to teach rather than just do.

Those technologies can also work in tandem, with a Grammarly for UI/UX design supporting the learning needed to better equip designers to use generative AI tools with a critical eye. Though AI can do a lot, a well-trained designer continues to offer a distinct lens. Even if a designer uses generative AI to cut out the pixel-pushing busy work, a good designer still ought to be able to evaluate the outputs and make changes to better reflect smart and usable design and tailor it to the brand or particular user body. No matter how “intelligent” artificial intelligence is, it does not employ original thinking or creativity in the human sense (Jacquez, 2023). Generative AI is only capable of crystallized intelligence, meaning intelligence built from prior experiences or known facts, whereas humans seem to be capable of a distinct form of creativity that surpasses that. As such, while products using generative AI are useful, integrating a legitimate understanding of what makes UI/UX design good based on known heuristics will remain important.

3. How it Should Work: The Technology

Given the need and significance which has been established for a Grammarly for design, the question of how exactly it ought to work remains. The specific technicalities of developing this plugin are outside the scope of this thesis, but a basic grounding of the AI/ML techniques which would be utilized remains relevant. To produce this plugin, a series of AI tools would be put into use in a very similar manner as other generative AI products such as Uizard which maps its AI technology as demonstrated in Figure 4.
Here is a breakdown of the elements used by Uizard shown in Figure 4, all of which would also be implemented in a Grammarly for UI/UX:

1. Gradient Descent: A widely-used optimization algorithm that leverages training data to facilitate learning over time in machine learning models and neural networks. The cost function within gradient descent serves as a gauge to measure the accuracy of the model with each iteration of parameter updates over time. The model adjusts its parameters until it reaches zero, meaning that it has been effectively optimized. One major consideration for understanding gradient descent is the learning rate. A small learning rate is more typical, meaning that the step size to reach the minimum is small and more exact. A higher learning rate creates larger steps and can accidentally overshoot the minimum but is more efficient. A visualization of different learning rates in gradient descent is included in Figure 5 (What Is Gradient Descent?, n.d.). While gradient descent is a helpful algorithm, there are also some limitations. Local minima and saddle points are two
particularly significant challenges. Local minima look similar to the global minimum that the algorithm is seeking because the slope increases on both sides, but they do not represent the true zero. Saddle points, meanwhile, are places where there is a local minimum on one side and a maximum on the other. Both of those are visualized in Figure 6 (What Is Gradient Descent?, n.d.). Despite those challenges, gradient descent remains a highly relevant and functional tool in creating a Grammarly for design because it is excellent at facilitating learning in neural networks.

**Figure 5:** Gradient descent learning rates (What Is Gradient Descent?, n.d.).

**Figure 6:** Gradient descent challenges (What Is Gradient Descent?, n.d.).
2. **Computational Design**: A method utilized in many fields which generally refers to using computational thinking and creation (Gun, 2023). It is similar to a typical design process in its phases and iterative manner but relies heavily on technology and rules-based systems to help create the solutions. It often results in more creative design solutions because they are generated from the broad knowledge base utilized in computation. This mechanism is relevant because it propels creative, computer-based design solutions.

3. **Heuristics**: The key to a Grammarly for design. Uizard uses heuristics like those previously described to establish parameters to generate good designs. A Grammarly for design, meanwhile, would identify a failing by the user to incorporate those heuristics in their design. It would then deliver feedback and recommendations for solutions based on those heuristics, generating examples of good design that would solve the problem.

4. **“Secret Sauce:”** Naturally, Uizard keeps some secrets to maintain a competitive edge in the market. This component does not require further explanation.

5. **Language Modeling**: A task in natural language processing that involves predicting the probability of a word or sequence of words based on the context of the surrounding words (Lutkevich, n.d.). Language models get trained on huge amounts of text data to learn language patterns like word frequencies, word order, and semantic relationships between words. Language models are used in a wide range of tasks including text generation, machine translation, speech recognition, sentiment analysis, and question-answering. There are different types of language models, a few common ones being n-gram models, recurrent neural network (RNN) models, and transformer models. N-gram models are based on statistical patterns of n-gram (n consecutive words) occurrences in the training data, while RNN and transformer models use deep neural
networks to capture long-range dependencies and contextual information in the text. These models are trained on large datasets and can generate coherent and contextually relevant text based on the input provided to them. Language modeling is significant because it can help generate text for feedback based on the user’s design error.

6. Computer Vision: A field of AI that focuses on enabling computers to interpret and understand visual information from the world, just like humans do with their eyes and brain (What Is Computer Vision?, n.d.). It involves algorithms and techniques that allow computers to analyze, process, and interpret visual data such as images and videos. Computer vision tasks can include image recognition, object detection, image segmentation, facial recognition, pose estimation, action recognition, and scene understanding, among others. Computer vision algorithms often use machine learning techniques, such as deep learning, to automatically learn patterns and features from large amounts of labeled data. Convolutional Neural Networks (CNNs) are a common type of deep learning model used in computer vision, as they are particularly effective in image recognition tasks. These models can be trained on large datasets to learn to recognize objects, scenes, and other visual patterns from images or videos. Computer vision would be applied to a Grammarly for design in analyzing the user’s designs to recognize areas for improvement.

7. Deep Neural Networks: A type of artificial neural network (ANN) architecture that consists of multiple layers of interconnected nodes, or neurons (Deep Neural Network - an Overview | ScienceDirect Topics, n.d.). These layers are stacked on top of each other, forming a deep architecture with many hidden layers, hence the term “deep.” Deep neural networks are designed to learn representations of data through a hierarchical feature
extraction process, where each layer captures increasingly abstract and complex features from the input data. The first layer, also known as the input layer, receives the raw data (such as images, audio, or text) as input, and subsequent layers, called hidden layers, gradually learn more abstract representations of the data. The final layer, called the output layer, produces the final prediction or decision based on the learned features. Deep neural networks are capable of automatically learning complex patterns and representations from large amounts of data, without the need for explicit feature engineering. They are highly expressive and can model nonlinear relationships, making them well-suited for a wide range of machine learning tasks, such as image and speech recognition, natural language processing, recommendation systems, and many others. Some popular types of deep neural networks include Convolutional Neural Networks (CNNs) for image and video processing, Recurrent Neural Networks (RNNs) for sequential data processing, Long Short-Term Memory (LSTM) networks for modeling sequential data with long-term dependencies, and Transformer networks for natural language processing tasks (Madaeni et al., 2022). Deep neural networks would be very useful in the process of learning up a model on mass amounts of “good design” example data.

The Uizard model encompasses all of the AI-based techniques which would be implemented in a Grammarly for design, but the specifics of how they would be used are different in some ways because of its distinct goal as a teaching tool. The tool would be similar to Uizard in that it would also train on thousands of examples of excellent design selected by AI based on several factors including website popularity. That process would establish a basis for how target UI/UX designs look and function such that the plugin could provide smart and accurate feedback and recommendations. In that sense, the AI techniques used to both identify
and generate good design should be very similar. However, the implementation of identifying and generating would be different. Specifically, certain parameters would be set like Grammarly to employ what we know about cognitive feedback theories. Those parameters would help filter what the AI model learns about “good design” into known heuristic categories to be intelligible and productive for someone learning UI/UX design. Moreover, the language modeling AI functions would extend to generating language for feedback. The more complete details of the AI/ML techniques that would be applied are outside of the scope of this thesis, but the above list and explanations should provide a sufficiently complete overview of the types of tools that would be used and how.

4. How it Should Work: The Design Heuristics

Beyond the AI/ML techniques that will act as the basis for a Grammarly for design, it is important to consider which design heuristics should be considered for this type of plugin. Similar to Grammarly, it should encompass both concrete rules and more nebulous best practices. Grammarly, for example, will recognize clear and certain grammatical guidelines such as if the user fails to put a period at the end of a sentence. For UI/UX, some of those more definitive heuristics should include (but not be limited to) key accessibility practices such as color contrast between background and text and background colors, colorblind accessibility, and font size. For instance, should a designer make a button with a text size that is too similar to the background color of the button, the plugin should recognize and suggest a correction for that because it would be hard to read for older users or users with color-related accessibility differences.

Beyond that, in the same way that Grammarly uses AI to address best practices in writing including concision, clarity, and tone, this plugin should tackle heuristics like those included in
Gestalt, Norman’s, Nielsen’s, and Universal Design principles. For example, the plugin should be able to identify if the designer is creating an error state for their webpage. If that error state does not clearly indicate what the user did wrong and how to solve the issue, the plugin would recommend a change based on Nielsen’s heuristic #9: Help users recognize, diagnose, and recover from errors. Another example is if the plugin recognizes that there is a large block of text that may cause user fatigue or difficulty of use, it should suggest breaking up that text based on Universal Design Principle #4: Perceptible information.

Importantly, while this thesis can provide some examples of the types of corrections that might be made by this plugin based on known design heuristics, the list of heuristics that should ultimately be encapsulated in the plugin should be iterative and contingent upon what the AI model learns about good design. Starting this type of plugin with known heuristics as parameters would be helpful as a jumping-off point, but the list should change and grow based on user feedback and how the model continues to evolve and improve. Additionally, the Supplementary Materials section provides several examples of the types of design heuristics that this plugin would address.

5. How it Should Work: The Feedback

As previously described, Grammarly expertly utilizes cognitive feedback principles to deliver effective writing feedback to its users. Because of the established similarities between grammar and design, the types of feedback that should be most useful to students ought to be similar which is why the type of feedback that Grammarly provides is so helpful in determining how UI/UX feedback should be delivered in this plugin.

Much of the academic literature on the effectiveness of Grammarly ties back to the three types of CF: direct, indirect, and meta-linguistic. The combination of these is so powerful
because different students have distinct responses to feedback, so addressing all possible learning styles is helpful. On that basis, a Grammarly for design should provide direct feedback through an explicit and timely delivery of the correct form or structure of the design. For example, the plugin might correct a user’s design mistake by providing an example of what their design might look like if the issue were solved. Additionally, the plugin should provide indirect feedback by giving comments after the error has been made without providing a corrected design. For Grammarly, this comes in the form of Insight Reports that address productivity, mastery, and vocabulary. Similarly, a Grammarly design should mirror that type of report with categories relevant to UI/UX design including productivity, mastery, accessibility, and aesthetics. It should come in the form of a weekly report emailed to users. The last form of CF is meta-linguistic feedback which focuses on the language used to communicate over the content of the message. In the context of grammar and writing, that feedback might take the form of explaining a grammatical rule or correcting pronunciation without explicitly describing the error. In the field of design, meta-linguistic feedback could take the form of presenting what a better design might look like without explaining the heuristics at play or, conversely, explaining a heuristic without pointing out a failing in the user’s design.

A Grammarly for design could also potentially provide customization options to users who do not want to receive all of those feedback types. For example, one user might be purely interested in direct feedback as they work with little desire to get indirect feedback reports to understand their overarching learning trajectory. Another user might want both indirect and meta-linguistic feedback to learn more holistically without getting specific, real-time corrections. Because everyone learns differently, and because people come to UI/UX design with varied
desires for learning outcomes, users should be able to modulate their experience to optimize it to their preferences.

Beyond CF, a Grammarly for Design should encompass the MISCA cognitive feedback model, centering the student and emphasizing message, implementation, context, and agents. In regards to the message, the feedback provided by the plugin should answer the three questions: “(1) Where is the student going? (goals, feed up); (2) How is the student going? (current state, feedback); and (3) Where to next? (closing the gap, feed forward)” (Panadero & Lipnevich, 2022). Those should be addressed in an overarching sense in the weekly insights report, but should also be considered in the real-time feedback in that the messaging should be clear and provide the student a sense of where they are and where they are going. In terms of implementation, the feedback should be mindful of the goals of the feedback and the potential cognitive processing. In other words, the feedback should be implemented in a manner that reflects the specific user and his or her goals. Additionally, the instructional context piece is important to this plugin in that the feedback needs to reach the students in the right condition, so delivery mode and timeliness are paramount. The final piece of the MISCA model, the agent, is relevant in that the design of the plugin must reflect its positionality as a digital agent that is providing feedback. The plugin is not a live teacher, so the type of feedback should not necessarily try to mimic what a real-life instructor might give, but rather be designed with the knowledge of how we interact with computers as distinct from people.

In addition to the cognitive basis of the feedback provided, the specific language used and how that would be developed is an important component of the functionality of the plugin. The feedback would be on assorted heuristics as previously described, and in the same way that the recommendations for what a better design might look like would be generated by an AI
model, the wording of the feedback would also be generated through language modeling techniques. Parameters would be set for how the feedback ought to be structured, but the specific wording would be created by AI based on the student’s particular preferences and needs. Moreover, the real-time feedback would be paired with an option to learn more about the heuristic addressed in the correction so that users can explore the issue in greater detail to inspire in-depth learning.

Beyond the cognitive theory behind how a Grammarly for design ought to provide feedback, examples of what feedback might actually look like are included in Supplementary Materials. That section also provides a sample view of the feedback provided in the weekly insights report.

6. Why it Should Work

Based on the previous discussion of the similarities between grammar and design and the established success of Grammarly as a tool for providing effective feedback that inspires real grammar learning, this plugin should function as a useful and productive tool for users to learn how to create better UI/UX design. There are certainly many differences between grammar and UI/UX design, and our cognitive experiences with each are incredibly different. Visual designs and text are encoded differently in our minds, but that distinction does not necessitate differences in how we best receive feedback to learn new concepts (Magliano et al., n.d.). Additionally, our early experiences with UI/UX design and grammar are incredibly different, as many people are taught formal grammar rules at a relatively young age while learning proper UI/UX heuristics and techniques comes far later. The learning trajectories for Grammarly versus a Grammarly for design would therefore be very different, but that does not mean that this plugin would be ineffective or unimportant. Despite the contrast between grammar and UI/UX design, a plugin
that properly uses AI/ML techniques to offer feedback accurately mirroring cognitive feedback principles on design heuristics should prove effective. Such a tool has the potential to help people at all stages of their UI/UX design journey, from beginners who are just starting to learn about design heuristics to professionals who are working to become most efficient and effective with their designs.
V. Conclusion and Future Work
Concluding Thoughts

Despite the large amount of research that has been conducted on cognitive feedback theories and UI/UX design heuristics, the two have thus far not been paired to create an effective learning tool in the same way that Grammarly functions as software to help teach grammar and improve writing skills. Therefore, this thesis has proposed a UI/UX design software plugin that would function as a Grammarly for design to inspire real learning. The plugin would rely on lessons from cognitive science including AI/ML techniques and cognitive theories of feedback to effectively target and recommend corrections on UI/UX design heuristics. Such a plugin would help fill a gap in UI/UX design software by not only addressing problems in the user’s design but also helping them learn throughout the process.

Future Work

This thesis has provided a theoretical framework for what a Grammarly for UI/UX design would look like, how it would function, and why it should work, but has neither gone into depth on the technical aspects nor provided a comprehensive view into exactly what it would look like and the technicalities of usage beyond the mockups included in the Supplementary Materials section. Those are therefore key future steps towards creating this plugin. Additional future work should include creating a minimum viable product (MVP) of the plugin to explore and test its functionality. An MVP could be a hardcoded plugin (rather than AI/ML-based) that addresses only a few design heuristics to best investigate how exactly the feedback is provided to students. That MVP could be used in user testing trials to gather feedback from users at different stages in their UI/UX design learning process. For example, a beginner might desire feedback on different heuristics or with more in-depth explanations than a professional designer in the same way that a
third grader might want different things from Grammarly than a Ph.D. student. A thorough user testing phase would therefore be incredibly valuable in the development of this plugin.

After a hardcoded MVP testing phase, the next important step would be a deeper dive into the AI/ML techniques that should be used in this plugin. This thesis is not technical, so the specifics of which techniques should be implemented and how were not explored in depth. Nonetheless, the research and development phase of that component of the plugin is necessary for its success as an agile and effective feedback tool.

Moving forward, the interactions of UI/UX design and cognition are ripe for investigation. Beyond the future work to be done on this particular plugin, this thesis also opens the door for further exploration of how to improve the process of learning UI/UX design. It also ushers in questions of the extent to which we need to learn concepts such as grammar and UI/UX design versus the degree to which we might be able to rely on the power of AI/ML. The possible implementations of ever more powerful AI/ML technology are incredibly vast, and this thesis provides an example of one small yet promising route for implementing those tools.
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VII. Supplementary Materials
Supplementary Materials

The following supplementary materials are screenshots of what this plugin might look like if it were implemented in Adobe XD, a popular UI/UX prototyping tool.

The recommendations generated by the plugin would remain hidden until the “Recommendations” button is clicked.
Once clicked, the recommendation will appear, pointing to the relevant design problem. A brief description of the error will be provided along with several selectable options for how to correct the problem. There is also a “Learn more” button.
The “Learn more” button leads to a pop-up with an article describing the issue in more detail.

The article will include why it is important and how to achieve a higher standard.
There will also be a weekly insights email, similar to the version that Grammarly sends out to premium users, which provides statistics on how the user is doing to remind them of their broader progress.