

TwIPS: A Large Language Model Powered Texting Application to Simplify Conversational Nuances for Autistic Users

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Autistic individuals often experience difficulties in conveying and interpreting emotional tone and non-literal nuances. Many also *mask*¹ their communication style to avoid being misconstrued by others, spending considerable time and mental effort in the process. To address these challenges in text-based communication, we present *TwIPS*², a prototype texting application powered by a large language model (LLM), which can assist users with: a) deciphering tone and meaning of incoming messages, b) ensuring the emotional tone of their message is in line with their intent and c) coming up with alternate phrasing for messages that could be misconstrued and received negatively by others. We leverage an AI-based simulation and a conversational script to evaluate TwIPS with 8 autistic participants in an in-lab setting. Our findings show TwIPS enabled a convenient way for participants to seek clarifications, provided a better alternative to tone indicators, and facilitated constructive reflection on writing technique and style. We also examined how autistic users utilize language for self-expression and interpretation in instant messaging and gathered feedback for enhancing our prototype. We discuss implications around balancing user-autonomy alongside AI-mediation, appropriating users' trust levels in AI systems, and identifying autistic users' customization needs in the context of AI-assisted communication.

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1 INTRODUCTION

Autism Spectrum Disorder (ASD) is a complex neuro-developmental disorder characterized by challenges in verbal and nonverbal communication, difficulties in social interactions, repetitive behaviors, and/or sensory sensitivities [1, 2]. It is one of the most common neuro-developmental disorders in the United States, currently observed at a prevalence rate of approximately 1 in 36 among 8-year-old children [3]. Many autistic individuals find it challenging to process non-verbal cues, such as facial expressions and body language, in face-to-face (FTF) interactions. Variations in vocal pitch and tone can add more layers of complexity to communication, making FTF interactions overwhelming for them. Prior work in disabilities and linguistics underscores a preference for written communication among autistic individuals, highlighting a tendency towards email and text messaging over FTF interactions [4]. This preference is attributed to the greater control and sensory ease provided by written communication [5]. However, studies indicate autistic individuals often experience difficulties in conveying and interpreting emotional tone and non-literal nuances in text-based communication, and standard chat features like GIFs and emojis contribute to these challenges instead of

¹Masking entails consciously or unconsciously altering one's behavior to conform to societal expectations.

²Texting with INTERPRET, PREVIEW, and SUGGEST

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addressing them [6, 7]. Many also mask their writing style to avoid being misconstrued by others, spending considerable time and mental effort in the process.

In the past, technology has been extensively utilized to enhance autism diagnosis methods [8, 9], therapeutic interventions [10, 11], social support tools [12, 13], and the overall quality of life [14, 15] of autistic individuals. Accessibility researchers have also advocated for the redesign of existing, mainstream applications to better meet the usability needs of autistic users [16–18]. More recently, advances in large language models (LLMs) such as ChatGPT [19] have opened up new possibilities for AI-assisted assistive communication. Their applications range from helping dyslexic individuals write emails [20] to providing social communication support for autistic individuals in professional settings [21]. Thus, LLMs have demonstrated their capability to interpret and generate text with a level of nuance that rivals human abilities in various practical scenarios [22]. Despite these advances, text-based communication challenges for autistic users persist, making it crucial and timely to investigate how state of the art in LLMs can be used to address them.

Informed by ideation with autistic users, the specific communication challenges they face and their design needs identified in prior work [6, 7], we introduce *TwIPS*, a novel texting application leveraging recent advances in LLMs [22], which enable it to grasp nuanced and implicit elements like emotional tone and intent from messages. Based on its understanding of these elements, it can dynamically generate feedback for users that is tailored to the specificities of each conversation. *TwIPS* comprises of three features (described in detail in §3) not found in traditional texting applications, all of which are powered by GPT-4 [22]:

- (1) **INTERPRET**: describes the overall tone and meaning of incoming messages, as well as individually identifies and explains ambiguous language elements, such as figurative language, sarcasm, and emojis.
- (2) **PREVIEW**: allows users to preview recipients’ likely emotional reaction to their message, helping them verify whether the emotional tone of their message comes across to the recipient as intended.
- (3) **SUGGEST**: complements **PREVIEW** by suggesting a differently phrased alternate message when needed - the suggested message preserves the intent of the original message, but has a softer tone.

As these features are in place, users retain full autonomy and agency to determine whether to adopt a suggestion, disagree with the provided feedback, or disregard it entirely.

Through an in-lab user-study with 8 autistic participants recruited from a university setting, ranging in age from 18 to 44, we gathered detailed qualitative feedback and survey responses on their a) use of language for self-expression and interpretation in instant messaging and b) perceptions of autonomy, accessibility and usefulness of *TwIPS*. The user-study leveraged a conversational script and an AI-based simulation to present participants with scenarios where they could utilize each of its three features, while maintaining user-autonomy, reproducibility and dynamicity across their experiences. Qualitative data showed participants demonstrated a strong inclination to actively engage in conversations instead of letting them become one-sided, though they found maintaining this balance difficult in text-based interactions. They also expressed their preference for clear and direct communication in messages, emphasized the importance of punctuation in personalization and emotional expression, and shared their strategies for masking while texting. For many participants, *TwIPS* enabled a convenient way for them to seek clarifications, provided a better alternative to tone indicators, and facilitated constructive reflection on writing technique. Participants’ suggestions for improving it centered on offering greater personalization and implementing measures to prevent users from over-relying on it. Our post-study 7-point Likert scale survey revealed 7 out of 8 participants favored continued use of *TwIPS*’ all three

features in their everyday chatting apps, with INTERPRET receiving the highest rating (avg. 6.25, s.d = 1.03), followed by PREVIEW (avg. = 5.88, s.d = 1.64), and SUGGEST (avg = 5.13, s.d = 1.72)³.

While we focus on evaluating TwIPS with an autistic audience in this study, we draw inspiration from the double empathy problem and recognize social interactions as an inherently collaborative process [23]. Hence, we advocate for deploying versions of the TwIPS prototype across both autistic and neurotypical users of chatting applications. Our current study, however, by focusing solely on the challenges, needs and experiences of autistic individuals, intersects with both the neurodiversity and medical models. It attempts to address communication challenges—akin to the medical model—while firmly embracing neurodiversity principles. This involves highlighting the need for mutual effort, encouraging understanding others’ perspectives, and adopting user-autonomy, choice and subjective feedback over rigid directives as a fundamental design choice. Moving forward, we plan to conduct studies specifically with neurotypical users to explore how they can better understand and interact with autistic individuals, and eventually with both user-groups together. This study serves as a first step in the direction of our vision, which we further detail in §6.

To summarize, we make these key contributions: 1) We design and implement TwIPS, an LLM-powered texting application, tailored to better meet the communication needs of autistic users; 2) We devise a novel methodology, leveraging an AI-based simulation and a conversational script, to evaluate all of TwIPS’ features in an in-lab setting with 8 autistic participants, while maintaining user-autonomy, reproducibility and dynamicity across their experiences; 3) We conduct a thorough exploration into autistic individuals use of language for self-expression and interpretation in instant messaging, closely examining the nuances of their communication styles; 4) We gather in-depth feedback on user perceptions of autonomy, accessibility and usefulness of AI-assistance in the context of instant messaging, identifying design and practical implications for augmenting text-based communication platforms with LLMs.

2 RELATED WORK

In this section, we review the communication preferences of autistic individuals, ongoing efforts to integrate AI assistance into human writing, and broader initiatives leveraging computing technologies in the context of ASD.

2.1 Communication Preferences in ASD

Numerous studies in disabilities and linguistics research have explored the communication preferences of autistic individuals. Howard et al. conducted a study involving 245 autistic adult participants, and on average, these individuals selected email and text-messaging as their preferred modes of communication over FTF conversations [4]. Nicolaidis et al. showed that there existed a link between the perceived success of healthcare interactions among autistic adults and the availability of written communication options [5]. Researchers posit that this is because written communication provides a higher degree of control, clarity, thinking time and sensory calm than FTF conversations [24, 25]. As a result, autistic individuals often rely on text-based digital communication modes, such as email and instant messaging features supported by social networking platforms, for interacting with others [26].

Given the popularity of text-based communication among autistic individuals, it becomes important to investigate whether the design of platforms that support text-based communication align with the needs and preferences of autistic individuals. A limited body of research in Human-Computer Interaction (HCI) literature attempts to answer this question through exploratory studies. Barros et al., in their critique of mainstream social media platforms, revealed that interpreting meaning and expressing emotional intent on social media platforms proved to be particularly difficult

³For each feature, participants were asked to express their level of disagreement (1) or agreement (7) with the following statement, "I would like to continue using the X feature in my everyday chatting app", where X was the name of the feature.

for autistic users [6]. Page et al. reaffirmed these challenges, and emphasized that non-literal nuances, such as sarcasm and jokes, are even harder to comprehend [7]. It is well known that autistic individuals may exhibit a cognitive style that is characterized by a preference for literal thinking and a tendency to interpret information in a concrete and straightforward manner [4]. Our research takes findings from these exploratory studies as a foundation to guide the design of an LLM-powered texting application tailored to cater to some of the challenges identified above.

2.2 AI Mediated Writing

AI has long been applied to enhance digital written communication. Writing assistants have traditionally been used to predict short, one word suggestions, like the next probable word in a phrase [27]. These are most common in emailing platforms, and Google has already deployed one on Gmail with access to millions of users [28]. The emergence of LLMs such as GPT-4 and BERT, however, is shifting this landscape [22, 29]. These models can not only produce longer pieces of text that are seemingly indistinguishable from human-written text, including the entire next likely sentence and creative content like poetry or story outlines, but also possess the capability to understand nuanced and implicit aspects such as intent and context. This is enabled by massive, attention based transformer models that are trained on extremely vast amounts of data [30].

In the realm of HCI research, there has been a growing interest in evaluating how LLMs can be responsibly utilized for assisted writing. Newman et al. explored the trade-offs of providing sentence-level suggestions as opposed to message-level suggestions [31], and the Wordcraft project embedded LLMs within a text editor to assist storytellers, helping them overcome writer’s block and sparking creativity [32]. Additionally, Goodman et al. developed LaMPPost, a browser plugin that employs LLMs to aid dyslexic users in crafting and revising emails, including generating email headers and previewing email content [20], and Jang et al. explored the use of LLMs by autistic adults in the workplace as an alternative to seeking social communication support from coworkers, friends, and family [21]. While our work expands on this line of research, HCI researchers have also dedicated efforts to establishing guidelines for responsible AI usage, aiming to minimize risks, biases, and ethical concerns, particularly in the context of AI-mediated human assistance [33–36].

2.3 Autism and Computing

Human-Computer Interaction researchers have been instrumental in developing new social support tools [12, 13] and therapeutic interventions [10, 11] for autistic individuals. Some of these techniques utilize simulations to create a controlled environment that enables users to safely explore and learn how to handle scenarios that could be challenging or risky in real life. For instance, Park et al. integrated an augmented reality (AR) interface with drama therapy to offer effective, universal, and accessible language therapy to autistic children [37], and Boyd et al. employed virtual reality (VR) to support proximity regulation for autistic individuals [38]. Prior research has also shown that use of technology promotes higher engagement among users [39], can be less resource-intensive compared to conventional therapy [40], and allows for customization that better addresses individual needs [41], moving away from a one-size-fits-all approach.

Given that autism varies greatly from person to person, the level of customization existing tools provide falls short of what is truly needed, underscoring the need for rapidly adaptive systems capable of supporting real-time content generation [42]. We explore if recent advances in generative AI [22, 29] can meet these customization needs in the specific context of AI-assisted instant messaging. In addition, most tools aim to help autistic users in enhancing their social skills, overlooking the collaborative nature of social interactions. We discuss how social interactions can be

conceptualized as fundamentally collaborative, and how this observation motivates distributing the responsibility to reduce communication breakdowns across all users.



Fig. 1. UI of the TwIPS prototype.

3 OVERVIEW OF TwIPS

This section motivates the design of TwIPS and describes each of its three features.

3.1 Motivation

The design of INTERPRET, PREVIEW and SUGGEST is inspired by challenges and concerns raised by autistic individuals, in prior work, related to expressing and interpreting emotions and intent online [6, 7]. These challenges include frequently misinterpreting others, struggling to understand nuanced language, and experiencing difficulties in making themselves understood, which forces them to constantly re-read and rewrite to align with neurotypical communication styles. Without proofreading, they could come off as blunt to others and prompt harsh reactions. These studies also highlight concerns over the extensive use of emojis and GIFs for self-expression, as both carry nuanced meanings that can vary with context, and emojis are just stylized versions of facial expressions which are hard to comprehend for many autistic individuals. Participants in our study reaffirmed many of these challenges.

3.2 Design and Functionality

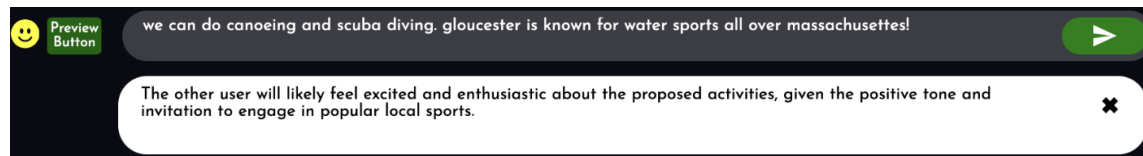
The user interface (UI) of the TwIPS prototype resembles the layout of standard chatting applications, featuring separate chat bubbles for received and sent messages, a text input box, the recipient's name, and buttons for sending messages and accessing emojis, as shown in Figure 1. Participant's messages are displayed on the screen's right side in dark-grey chat bubbles, and incoming messages are shown on the left side in light-grey chat bubbles. Additional UI elements to



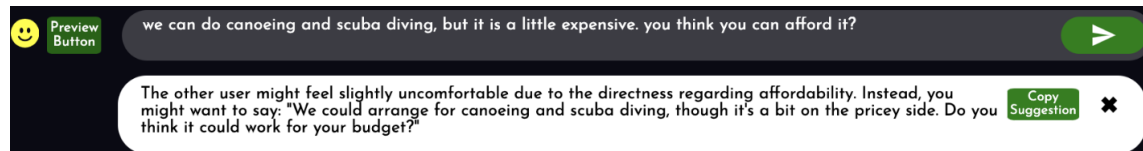
Fig. 2. INTERPRET in Action.

support INTERPRET, PREVIEW and SUGGEST are described in detail in the subsequent subsections below. INTERPRET is designed to help users in understanding messages from others, whereas PREVIEW and SUGGEST are intended to assist them in composing their own messages.

3.2.1 INTERPRET. This feature, as implied by its name, is designed to help users comprehend others' messages. It serves two functions: a) it describes the overall tone and meaning and b) it individually identifies and explain ambiguous language elements, such as phrases with sarcasm or metaphors, and emojis, in incoming messages. A message containing ambiguous language elements is marked with a grey circular symbol in the upper left corner of its chat bubble, and users can hover over any chat bubble with this symbol to reveal the underlined ambiguous language element(s), as shown in Figures 2a and 2b, respectively. Clicking on an underlined language element expands the chat bubble to reveal its meaning, and clicking anywhere else on the chat bubble expands it to show the overall tone and meaning of the message, as shown in Figures 2c and 2d, respectively. Only one type of explanation, either for ambiguous elements or the overall message, is displayed at a time.



(a) PREVIEW describes how the recipient of the message may feel upon reading the user's message. In this example, the message and preview were fairly positive, hence SUGGEST was not triggered and an alternative message was not produced.



(b) In this example, a negative preview and an alternative message were produced by PREVIEW and SUGGEST, respectively.

Fig. 3. PREVIEW and SUGGEST in Action.

3.2.2 PREVIEW. This feature is intended to help participants compose messages. It serves two primary functions. First, it enables users to preview recipients' likely emotional reaction to their message, helping them ensure the emotional tone of their message comes across as intended to the recipient and make adjustments to it if needed. Users can toggle it through the 'Preview' button positioned next to the emoji button. After toggling PREVIEW, a new text box appears below the message writing box to display the preview, which can be positive or negative, as shown in Figures 3a and 3b, respectively. The new text box disappears automatically once the user clicks on the 'Send' button or the cross symbol present on its far-right side. Second, PREVIEW flags messages as *blunt* or *not blunt*, whenever the user clicks the 'Preview' or 'Send' buttons. In the former scenario i.e., a message is flagged as blunt, it generates a negative preview and triggers SUGGEST to generate an alternative message. If the user still wants to send their original message, they can click on the 'Send' button again to bypass PREVIEW's flagging functionality.

3.2.3 Suggest. This feature complements PREVIEW by generating a differently phrased but softer, or *less blunt*, alternate message for any message flagged as blunt by PREVIEW, while preserving the intent of the user's message in the alternative. The suggested message is appended to the feedback provided by PREVIEW, as shown in Figure 3b. Users can click on the 'Copy Button' to copy the suggestion to the message writing text box. PREVIEW and SUGGEST work in conjunction with one another, with PREVIEW providing an explanation as to why the user should consider the suggested alternative. PREVIEW bases its explanations off the most likely reaction/perspective of the recipient, with the hope that this will make them sound less corrective and more subjective as opposed to sounding instructional and rigid, ultimately leaving the decision to take or leave the suggested alternative up to the user. The goal is to provide users with context, and interpretation, not to censor or take away someone's voice. And that the choice to use the suggestion or not is entirely up to the user.

3.3 Prompting Strategy

Writing effective prompts requires thorough testing and iterative refinement to elicit dependable and accurate responses from the LLM. During development, we experimented with various prompts before finalizing the ones employed in our final prototype. The prompt templates used for each of the three features in TwIPS are provided in Appendix A.

P#	Diagnosis	Self-Identifying	Age	Gender	Texting Usage
P1	Y	Y	25-34	Female	Very Frequent
P2	Y	Y	18-24	Female	Very Frequent
P3	Y	Y	18-24	Non-binary/third gender	Very Frequent
P4	N	Y	35-44	Female	Very Frequent
P5	N	Y	18-24	Male	Very Frequent
P6	N	Y	18-24	Non-binary/third gender	Very Frequent
P7	Y	Y	18-24	Male	Very Frequent
P8	N	Y	18-24	Female	Very Frequent

Table 1. Information about participants.

We used GPT4’s code API (version: 1106-preview) through Microsoft Azure [43]. We applied few-shot learning to our prompts where possible, which is a well-known technique to design custom prompts by incorporating several examples of a task to guide a language model as it performs that task [20, 44, 45]. Additionally, we appended the entire conversational history to all prompts, ensuring the LLM had a comprehensive understanding of the conversation’s context. We also made feature-specific modifications to prompts where needed. We specified to check for emojis, figurative language, and phrases with an indirect meaning in the prompt used with INTERPRET. We pre-fetched the tone, meaning, and ambiguous language elements for each message as soon as it was sent, but only retrieved the explanation for an ambiguous language element when users clicked on it. In the prompt used with SUGGEST, we made it explicit that the writing style and stance taken in the suggested alternative should match the writing style and stance of the user’s original message. While we do not claim that these prompts are ideal, they were adequate for the purposes of our in-lab study within a controlled environment as they provided consistent, reliable results.

4 METHODOLOGY

4.1 Recruitment

Participants were recruited from a university setting in USA, over a period of two months, through flyers posted in various buildings around campus. Interested individuals completed a screening survey to ascertain their eligibility. The inclusion criteria were: a) being aged eighteen years or older b) fluency in English reading and writing c) ability to perform basic computer tasks, and d) having a formal autism diagnosis or self-identifying as autistic. Recognizing disparities in access to diagnostic methods and procedures, we did not require a formal autism diagnosis to be eligible to participate in the study [46] similar to other recent studies involving neurodivergent populations [20, 47].

A total of fourteen participants were recruited, out of which eight enrolled and completed the study. Table 1 shows information about the participants. Each user-study session lasted approximately two hours. Participants received an Amazon gift voucher worth twenty-five USD upon the study’s completion. The study environment was a quiet room with adjustable lighting to accommodate participant needs. Additional accommodations, such as travel assistance or specific lighting requirements, if any, were identified through the screening survey and later addressed. This study adhered to ethical guidelines and was approved by the institution’s Social, Behavioral, and Educational Research Institutional Review Board (IRB).

4.2 User Study Overview

This sub-section outlines the design of our two-phased user study. The user-study was carefully designed to provide users with conversational scenarios where they could utilize each of the three features in TwIPS, while ensuring user-autonomy, consistency and dynamicity across their experiences. Before each phase, participants received a handout detailing the prototype's features and tasks associated with that phase, along with a demonstration by a member of the research team. Participants were free to ask questions at any time.

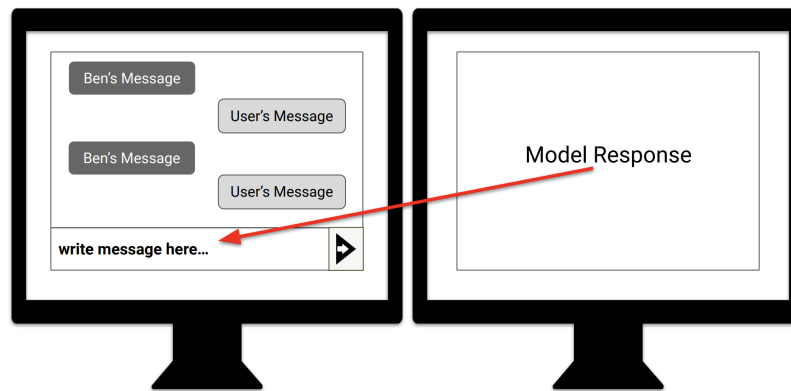


Fig. 4. In phase 1, participants were provided with two monitors. The TwIPS prototype, used for exchanging messages with Ben, is on the left monitor while the model response is displayed on the right monitor. The model response on the right screen was updated automatically each time Ben sent a new message.

4.2.1 Phase One: A Scripted Conversational Scenario. In phase one, each participant engaged in a simulated one-on-one conversation with an imaginary character, Ben. To facilitate the simulation, the research team came up with a scripted conversation between Ben and participants prior to the study. The script centered around planning a birthday surprise for Jack, who was assumed to be a mutual friend of Ben and the participants. The same script was used for all participants and it is provided in Appendix B. Participants' messages in the script were a mix of blunt and non-blunt messages - this was not revealed to them. These served as *model responses* that participants could send to Ben, and were revealed to them one-by-one, each paired with one of Ben's messages, as shown in Figure 4. Participants could either use the model response as-is, modify it, write a new response or choose the alternative suggested by SUGGEST when available, if they found the model response to be too blunt to send. Participants were given ample time to decide how they wanted to respond to Ben, explain the rationale behind their decision, and thoroughly describe their impressions of the model responses as well as the feedback and suggestions provided by PREVIEW and SUGGEST, respectively. Participants were encouraged to think aloud during phase one.

We imposed a number of constraints as part of phase one's design. First, we only introduced we concealed the 'Preview' button from participants, so PREVIEW was set to activate only automatically in phase 1 i.e., if a participant was blunt in their response to Ben, PREVIEW might flag and prevent it from getting sent. Second, we intentionally included several blunt messages in the set of model responses provided to participants. Third, participants were instructed that if they wanted to modify the model response, or write a new response, they should do so in a manner that might alter its wording/sentence structure but maintain its semantics/stance. This design cleverly allowed us to examine in an in-lab setting how our participants prefer to communicate in situations requiring directness or bluntness, and

observe their reactions when they sent a blunt message, either unknowingly or knowingly, and were prompted by PREVIEW and SUGGEST to consider revising it. At the same time, it granted participants the freedom to modify or rewrite their responses, decide whether to take up a suggestion or ignore it, and thoroughly explain the rationale behind their decisions.

4.2.2 Phase Two: A Nuanced AI-based Simulation. In phase two, participants initiated a second conversation with Ben with the goal to plan a trip with him to Gloucester, a waterfront city in Massachusetts. To aid participants in initiating the conversation, background information about notable destinations in Gloucester was provided to them. Participants were encouraged to compose messages in their own, unique writing styles. To simulate a more realistic and dynamic conversation, Ben was configured to be an AI-persona whose responses were dynamically generated on the fly via GPT4 in phase two.

Additionally, GPT4 was configured through prompts to introduce ambiguous language elements such as positive sarcasm, figurative language, emojis and jokes in its responses. This ensured that Ben's AI-persona acted in a way that prompted participants to use INTERPRET, thereby testing its capability to identify and explain ambiguous language elements. Contrasting with phase 1, where PREVIEW was set to activate only automatically, phase 2 offered participants the option to manually toggle it through the 'Preview' button, which they could click before sending a message. This enabled us to observe how users interact with PREVIEW and SUGGEST when given more control. Participants were encouraged to explore and experiment with all 3 features to gain a holistic understanding of the application's features. In both phases, participants were informed that Ben was not a real human to allow them to stress our prototype with all kinds of messages without the fear of actually hurting him.

4.3 Data Collection and Analysis

Upon completing both phases of the study, participants engaged in a semi-structured interview followed by a survey. The post-study semi-structured interview delved into participants' perceptions of TwIPS' usefulness, suggestions for improvement, and their experience with existing texting applications. Following the interview, participants completed a survey comprising 19 Likert-scale questions. Each question was rated on a 7-point scale, ranging from 'Completely Disagree (1)' to 'Completely Agree (7)', with an additional option available for questions where standard options were not applicable. We adapted our survey design from the survey used by Goodman et al [20]. The survey results provided a holistic overview of user perceptions concerning each feature as well as the prototype as a whole, and qualitative insights helped explain them. The primary themes in the survey included the prototype's usefulness, correctness, and impact on participants' sense of self-autonomy. Throughout the duration of the study, participant's audio and screen were recorded for later analysis. Written consent was obtained from each participant before the start of the study.

Given our small sample size (N=8), we state descriptive statistics with survey results, such as average and standard deviation, along with the verbatim survey question. To conduct qualitative analysis, we used Braun and Clarke's approach to thematic coding [48] using a deductive approach. Prior to the study, we developed a set of deductive codes to categorize: existing challenges with texting; communication style and preferences for self-expression and interpretation in text; positives, negatives, and improvements for each feature; and perceptions of self-autonomy and accessibility. A member of the research team transcribed the data and contextualised the transcripts with additional information from screen recordings. After importing the transcripts in NVivo, they extracted relevant quotes for each code, grouped these into themes, discussed the themes with other team members, and then reviewed and refined them.

A second member, who was not part of the initial study team, validated the themes and the data associated with each theme. A similar approach was employed by Ahsen et. al [42].

5 FINDINGS

In this section, we report our findings on participants' communication styles and preferences for text-based communication, their experience using the TwIPS prototype, and their suggestions for improving it.

5.1 Communication Style and Preferences

5.1.1 Sustaining One's Weight. Most participants, including P1, P2, P3, P4, P5, P6, and P8, demonstrated a strong inclination to maintain their own weight in the conversation. In addition to making affirmations or negations to Ben's questions (Ben was the AI character involved in the user study), participants made a conscious effort to pose their own questions and steer the conversation. In instances of disagreement or while expressing disinterest towards Ben's suggestions, they proposed alternative suggestions to prevent the burden of generating new ideas from falling on Ben. At one such instance, Ben asked P4 if they knew Jack's (Jack was assumed to be a mutual friend of Ben and the participant) birthday was coming up, and P4 remarked, *"A response like 'Yeah, I know!' will shut down the conversation and put the burden on Ben to decide what to talk about next. I'll add 'Should we do something [to celebrate Jack's birthday]?' to my response"*. P8 resonated with this remark. Moreover, P1 highlighted the struggle to maintain balance in text-based conversations is a common challenge faced by autistic individuals, *"Maintaining a balance in text messages is difficult. We often respond directly to the question posed without contributing equally to the conversation's flow. When I talk to people who are not autistic, their biggest complaint when texting autistic people all the time is: I feel like they do not want to talk to me because they only answer my question but never continue the conversation"*. In this way, a key aspect of participants' thought process involved recognizing that simply disagreeing without offering alternatives, or responding to questions without prompting further discussion, might shift the burden of maintaining the conversation's momentum onto others.

5.1.2 Clarity and Directness. Numerous participants, specifically P1, P3, P4, P5, P6, P7 and P8, shared that they strive to text in a clear and direct manner, with the aim of minimizing the chances of being misinterpreted by others. P4 emphasized it was necessary to communicate clearly and directly, particularly with other neurodivergent individuals, as even slight ambiguities could result in them getting caught in a non-stop cycle of overthinking. For P5, being straightforward and concise reduced the chances of misinterpretation in general too, *"...the fewer words you use and the more to the point it [the message] is, there are less extra things for people to misinterpret."* Conversely, P4, P6, and P2 asserted being direct might not be suitable in certain scenarios, like interactions with unfamiliar people or in the midst of disagreements. When P4 wanted to express disinterest in Ben's suggestion, they explained, *"Since I don't know Ben very well, I'm not going to push hard on his expressed preference. If it was someone I knew well, I might be more blunt."* In this way, participants highlighted the importance of clarity and directness in texting, emphasizing that the level of directness must be adjusted according to the situational context for effective communication.

5.1.3 Masking in Text. Masking entails consciously or unconsciously altering one's behavior to conform to societal expectations - autistic individuals often feel the need to mask while interacting with neurotypical individuals. Our participants explained the different factors they consider and strategies they use to effectively mask in text. P3 believed it was necessary to mask with strangers until a reasonable level of familiarity was reached, at which point they could reveal their true communication style without fear of judgement. For P4, masking needed to be done more pervasively to adhere to social norms, and P1 rewrote any message they needed to mask. This was a flexibility afforded by texting,

unlike in FTF interactions where words are spoken without the opportunity for revision, *"I typically start typing out my response, and then if I realize that I need to mask, I end up fully rewriting it. It's the same idea of like turning everything into sounding nice even when you aren't being nice"*. P4 likened masking to a "transparency slider", explaining how they adjust it to reveal varying degrees of their personality in different contexts or selectively display certain aspects of it. P4 and P7 stressed on the significance of maintaining authenticity while masking, with P4 stating, *"If you just copy somebody with your masking, then you look like somebody else, and people will always interact with you that way. Whereas, if you make it yours, but more like a translator than a cover, then it's more like you, except understandable to people who are not"*. This illustrates that autistic users mask to conform to the norms of text-based conversation, which can differ significantly from those of FTF conversations, and make a concerted effort to preserve the authenticity of their writing style.

5.1.4 Punctuation and Crutches. P1, P2, P3, P4, P5 and P7 pointed out that punctuation plays a key role in tone interpretation and the personalization of one's writing style. P1 associated imperfect punctuation and spelling with an amicable or colloquial tone, and linked precise punctuation, such as using a single question mark instead of several, to seriousness and stronger emotions like bluntness or annoyance. For P2 and P5, exclamation points typically signalled positivity and excitement, unless the message inherently carried a negative meaning. P4 and P7 consistently capitalized the first letter of each word in the message and avoided slang, as they believed that using non-standard words and incorrect punctuation made the messages sound unlike their authentic self. P4 expressed, *"That doesn't sound like me. So, I would never, ever send a message that had non-existent words"*. Furthermore, P1 and P2 employed conversational aids to more accurately express their tone. P2 mentioned that sometimes they include a disclaimer when feeling too fatigued to invest the effort required to articulately phrase their message. The disclaimer was basically a follow-up message, requesting the recipient to interpret the previous message in the specific tone intended by the sender. Similarly, P1 noted they frequently include extra 'context' to explain their punctuation choices. By 'context', P1 meant adding tone indicators like '/sarcastic' and '/excited' at the end of their messages to clearly convey the intended tone, *"I often put a lot of context in my message, because messaging people is very stressful... if I use a specific punctuation mark, I'll explain its purpose"*.

5.1.5 Resolution Strategies. Based on past experience, participants reported it was challenging for them to discern tone and meaning within their own text messages, as well others' messages. To counteract this, they adopted a range of strategies. P1 shared that sometimes, they seek help from their close friends before sending out a message or email, *"I will send it [a screenshot] to people and be like: does this sound okay? And they'll be like: that sounds like you're heavily critiquing that person. You should definitely change xyz things. So, it takes me a long time, because I have to rewrite a lot of what I say"*. For P3 and P6, vocalizing other's messages enhanced their understanding of the intended tone. P2, P3 and P7 preferred to inquire the sender directly to avoid making any assumptions or misinterpretations about their tone, while P5 felt it was better to resolve ambiguities in person, expressing worry that trying to clarify something over text could further add to the confusion, *"I'm uncertain if Ben is being passive-aggressive. Confronting him might just complicate things if he's not actually being that way. So, I won't bring it up, at least not over text"*.

5.2 Feedback on the TwIPS Prototype

5.2.1 Reactions to INTERPRET.

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Seeking Clarification. For multiple participants, interpreting tone and meaning in text was challenging and often necessitated clarification from the sender. In instances where asking for clarification was not possible, participants expressed INTERPET could be incredibly helpful. Specifically, P3 underscored its utility in group chats and on dating apps. *"In group chats, when you're not part of the ongoing conversation, it's hard to tell if you're missing context"*, and INTERPRET could help with clarifications without directly inquiring the sender in front of other groups members. P3 identified flirting as one of their primary challenges as a user of dating apps, *"flirting depends on subtlety and one-on-one responses - the difficulty lies in knowing when to shift the conversation or topic"*. They emphasized *"first impressions are basically everything"* in this context, and INTERPRET could play a pivotal role in helping users understand innuendos and ensuring responses align with the intended tone, thereby helping them *"say the right thing"* and navigate the *"make-or-break"* nature of initial interactions more effectively. Similarly, P5 and P2 felt that INTERPRET could be beneficial in the initial stages of talking to or befriending strangers. Perhaps, P1 believed INTERPRET could potentially benefit both neurotypical and autistic users, explaining *"people who don't feel comfortable asking for clarification could benefit from it, as well as neurotypical individuals, for whom having to constantly explain their tone can get annoying"*. Overall, participants strongly agreed with the statement *"The application's interpret feature enabled me to better understand the overall tone and meaning of messages"* in the post-study survey (avg. = 6, s.d = 1.07).

INTERPRET or Tone Indicators. Some participants compared INTERPRET to using tone indicators. Tone indicators are short abbreviations used at the end of a message to clarify the sender's emotional tone, helping the receiver understand the intended sentiment, such as seriousness, sarcasm, or humor. For example, *"/s"* indicates sarcasm, while *"/j"* denotes joking. P6 described tone indicators as *"pretty vague because they are limited to a small number of high-level adjectives like 'sarcastic' or 'joking'"*, and liked how INTERPRET, on the other hand, is more nuanced as it *"uses multiple, very specific adjectives"* to describe tone. For P6, one's understanding of tone significantly influenced their interpretation of the message's meaning. Since INTERPRET not only provided tone but also the meaning, it made this connection clearer; for this reason, INTERPRET surpassed the clarity provided by tone indicators for them. While P2 might not utilize INTERPRET for every message, they saw its value in moments where they would want to double-check their understanding, particularly when dealing with sarcasm or metaphors.

Ambiguous Language Elements. In addition to clarifying the overall tone and meaning, INTERPRET was designed to identify and explain ambiguous language elements, such as figurative phrases and emojis. P2 appreciated how the two features were subtly integrated, *"the underlined phrases only appear when I hover over the message, rather than bombarding me with them. This makes the experience less overwhelming and more user-friendly"*. P4 found the underlining helpful as *"sometimes it's hard to even identify the emoji"*, however, they expressed concern that if too many components in a message were ambiguous, it would be *"anxiety inducing to have all of them underlined"*. For P2, P6, and P8 the ability to delve into specific phrases added value in its own right, because one could grasp the gist of the message but might lack understanding of certain phrases within it. P2 argued *"the more information provided, the better, as there might be instances where I grasp the overall meaning but not specific phrases or emojis in the message, such as 'pops on the beach' [a phrase Ben used that P2 did not know of]"*.

Moreover, P2, P3, P4, P6, P7 and P8 saw value in INTERPRET's ability to explain emojis. For P2, *"using the skull emoji to indicate laughter rather than the usual laughing emoji can be confusing, so having emoji explanations along with the context in which it's commonly used was really helpful"*. P4 appreciated the range of emojis INTERPRET covered, and how it handled emojis combinations, *"the range of emojis it can explain is excellent. I like how emoji combinations are explained differently, because the meanings of individual emojis can change when combined"*. Having emoji explanations upfront

was convenient for P1, and P4 echoed this sentiment, *"it's possible to search for phrases elsewhere, but having immediate explanations especially for emojis, that are challenging to look up, is very convenient"*. Conversely, P1 and P5 deemed explanations of individual language elements redundant. P1 attributed this to the nature of emojis Ben employed in their interaction, which they found to be self-explanatory, *"Ben seemed to use emojis not as word replacements but more as expressions of excitement, silliness, or perhaps just for the novelty"*. Overall, participants strongly agreed with the statement *"The application's interpret feature correctly interpreted the overall tone and meaning of messages, taking into account the conversation's context"* (avg. = 6.5, s.d = 0.76).

5.2.2 Reactions to PREVIEW.

Facilitating Reflection. Participants were of the view that PREVIEW facilitated constructive reflection on writing technique and style. P4 identified reflection as a vital part of learning to communicate effectively and independently, *"PREVIEW helps me develop a mental model of what others might find rude, dismissive, or offensive, going beyond resolving a single incident. It's so important to know why something is bad in order to be able to pattern match for future"*. P2 and P6 echoed this sentiment, describing that PREVIEW helped them identify aspects of their messages that could be improved but were overlooked by them. For example, P6 stated, *"PREVIEW made me aware of how I might be suggesting my preferences as the only options without considering Ben's choice"*. Similarly, P2 observed, *"I thought my message was good - but then PREVIEW made me realise what was off"*. P4 expressed that PREVIEW not only helped them find areas for improvement, but also indicated how to make those improvements. For instance, P4 found value in the advice to gradually lead into the chat while initializing their chat with Ben, *"guidance on prefacing my main points has been incredibly beneficial. It has prompted me to consider the extent of introductory conversation necessary before diving into the main topic"*. In addition, P1 differentiated her experience as an autistic woman from that of autistic men, *"as women, a lot of our language is already expected to be curved, like our emails have to have exclamation points and, you know, we have to try really hard to sound kind. I feel like this [PREVIEW] would benefit a lot of the autistic men that I know. It would enable useful self-reflection that a lot of autistic men, I think, need. A lot of autistic women are diagnosed later in life, and at that point they have learnt to mask really effectively. So many women, including myself, have mitigated the problems that this is trying to solve in a variety of ways. But I don't know a single autistic man, and I know a good amount, that wouldn't benefit from this"*. P1 further expressed that before sending an email or message, they often obtain feedback on it from others, and PREVIEW was a more convenient way for doing the same thing, *"right now, I require the help of a community [close friends] where I have to send them a screenshot and be like does this sound okay to you?"*. Overall, participants expressed strong agreement with the statement *"The application's preview feature can help prevent misunderstandings as it enables users to preview recipients' likely response to their message and make adjustments to it before sending"* (avg. = 6.63, s.d = 0.74).

To Toggle or Not. In phase 1 of the user study, PREVIEW was configured to activate automatically for blunt messages. In phase 2, participants were given the option to toggle PREVIEW via a button before sending a message, in addition to it activating automatically. Participants held mixed opinions on whether they should have the option to manually toggle PREVIEW. P8 compared PREVIEW with their current approach to effective communication, *"There's a little checklist in my head that I want to run through before I say things. Because I run through that checklist anyway, I don't feel like I lost any autonomy [with PREVIEW automatically doing those checks for me]. So, it fits very nicely into my life"*. P6 highlighted that many autistic individuals may already experience heightened levels of overthinking before sending a message, and introducing the option to manually toggle PREVIEW could exacerbate this tendency and users would be *"bound to*

overthink more". In P6's and P8's opinion, automatic PREVIEW could prevent folks from unnecessarily toggling PREVIEW, as it would automatically activate if an issue was detected. However, P6 acknowledged that manually toggling PREVIEW "reduces a bit of anxiety because you don't have to hit the send button and then wait for an evaluation, alleviating a lot of pressure since all the revision work happens before you press send". Similarly, P7 compared the feeling of constant scrutiny and anxiety resulting from automatic PREVIEW to the sword of Damocles in phase 1 of the study⁴. However, participants noted in phase 2 that manually toggling PREVIEW could also result in positive feedback. P7 and P8 felt "acknowledged" and "cared for" when PREVIEW described some of their messages as "understanding", "affirmative" and "conscientious". Additionally, P2, P3 and P8 saw the value of being able to manually toggle PREVIEW in certain circumstances. P2 expressed, "if I'm texting my dad, I probably wouldn't use it. However, when I am texting someone I'm not particularly close to, or having a difficult conversation with a friend, I'd likely use it to ensure that I'm conveying my message as intended".

Misaligned Feedback. Occasionally, participants indicated that although PREVIEW's judgement was accurate, it was exactly what they wanted to convey, and were unconvinced that they should not send their message. For instance, the following feedback was provided by PREVIEW to P2 when they expressed to Ben a clear preference for not inviting other people to the movies because coordinating with large groups was a hassle: 'Your message might be perceived as dismissive by Ben, as it is highlighting a dislike for dealing with large groups'. P2 swiftly responded with "but conveying that is exactly the point of my message". Similarly, P3 expressed at one instance "I am definitely acting unenthusiastic or uninterested [the words unenthusiastic and uninterested were part of the feedback provided by PREVIEW], which is my goal with this response". P1, P3 and P6 echoed these sentiments. Moreover, P2 pointed out that a message that appears blunt or insulting might be perfectly normal in conversations with a friend that they are accustomed to talking like that. They feared PREVIEW's accuracy "could be hit or miss depending on the specific dynamics of the interaction" if it is not able to adapt to those dynamics. Overall, participants valued the option to ignore the feedback if they wanted and continue to send their original message, and disagreed with the following statement: "The application's ability to automatically prevent an inappropriately toned message from being sent negatively impacts user autonomy" (avg. = 2.25, s.d. = 1.98).

5.2.3 Reactions to SUGGEST.

Self-expression in the Suggested Alternatives. Alternate messages produced by SUGGEST were perceived by participants as softer and more thoughtful, and included justifications with strong opinions or decisions to make them appear less imposing. For instance, when SUGGEST changed the message "coordinating with others is a hassle" to "organising with a lot of people might complicate our plans, don't you think?", P3 commented "the word 'hassle' is definitely replaceable. The addition of 'don't you think' makes it less confrontational, because it is like we are working together. It is a more tactful way to express the same sentiment". Similarly, in phase 1, SUGGEST changed "Just as long as we don't go to a seafood restaurant" to "Just a heads up, I'm not really a seafood fan!", and P6 expressed "I [in my original message] come across as if I am imposing a rule, implying that seafood should be completely off the table, whereas the suggestion sounds gentler and more like offering a consideration". P2, P4, P5 and P7 expressed similar opinions.

In certain instances, however, especially in scenarios of disagreement, participants expressed SUGGEST appeared to undermine their opinions by softening their original message so much that it reduced the intensity and emotional depth more than required. For instance, when SUGGEST changed the message "umm... is that [inviting others to the birthday party] necessary?" to "what do you think? Should we keep it small or invite everyone?", P4 stated "It [the

⁴In the story of Damocles, a servant envies the king's power but realizes the constant danger the king faces. The king offers the servant the opportunity to experience his power for a day but with the danger of a sword hanging over his head by a single strand of hair, symbolizing the constant risk and responsibility of leadership.

alternative provided by SUGGEST] does not express the fact that I have a preference [for a small group]. If I took all of the suggestions, without editing any of them, I feel I would have a very passive tone and not be able to give my input. The rephrasing introduces flexibility but at the expense of omitting my preference for a smaller group. I think I'm more likely to be unhappy if I don't ever express my own preferences". P1, P3, P7 and P8 echoed these sentiments, highlighting SUGGEST hindered their ability to clearly express their preferences. Participants valued the option to ignore the suggestion if they wanted and continue to send their original message, disagreeing with the statement "The application's ability to generate and suggest alternative messages negatively impacts user autonomy" (avg. = 2.25, s.d. = 1.98).

Need for Personalization. At many instances, participants felt the suggested alternative messages did not have a human-like writing style, were not personalized to match their own, and used words that did not resonate with the dynamics of the rest of the conversation. For example, when SUGGEST changed the message "i don't think we need to [invite others]" to "I guess it could be more intimate if it's just us", P1 commented "I think it's kind of overdoing it because it's not necessarily supposed to be intimate, right? I think the word choice is kind of bad in this one". P4 expressed the alternate messages were often "AI-ish and pretty generic..." and P3 found one of the suggestions to be "a little wordy". Overall, participants disagreed with the statement "It felt as if the message suggestions generated by the application's suggest feature had been written by me" (avg. = 3, s.d. = 1.93). As a result, participants resorted to a number of strategies for utilizing the alternate message in some way instead of using it to replace their original message. For instance, P4 adjusted the alternative suggestion to more closely mirror their own style by matching the word construction to their typical usage, but found it beneficial that the suggested message contained the right content, which they could use without having to come up with it themselves. P3, P4, and P6 chose to selectively integrate phrases from the suggested alternate message into their original message, instead of using the suggested alternative in its entirety. P3 noted that just reading the alternate message also helped them understand what aspects of their original message could be improved.

5.3 Suggestions for Improvement

Appropriating Trust in INTERPRET. P4 emphasized the importance of establishing appropriate trust levels in INTERPRET, cautioning against over-reliance, "I don't want myself to think that this can do more than it really can... Now I may over trust it and now we have a problem because I'm going to trust it when I shouldn't trust it". They suggested incorporating a visual 'certainty measure' to inform users about INTERPRET's confidence in the interpretations it made. P4 argued this would be particularly valuable in scenarios involving nuanced elements like slang or inside jokes that could confuse the system itself. In their opinion, this would help users build a balanced level of trust, encouraging them to also rely on their instincts, "this might be really valuable in building the right amount of trust so that people know to trust their own instincts too" and consider the possibility of errors in INTERPRET's judgment, "having a certainty measure will also cue people to think about the fact that the computer could be wrong". In addition, P1 and P8 expressed the need to be able to see for senders what was being shown to recipients. P1 expressed, "it would allow me to see, 'Oh yeah, that's about right', and provide the opportunity to correct it if not".

Expanding PREVIEW. While participants liked the concept of PREVIEW, they believed it could be expanded upon. In P2's opinion, "it's not just about how the recipient takes your message, but more importantly, it's about ensuring that what you're sending accurately reflects what you intend to say". They suggested that, alongside recipient reactions, it would be useful to be able to preview a message's tone and meaning, as this would guarantee that the message conveyed precisely what the sender intended. For P1, who struggled with maintaining their weight in conversations, it was a perfect use-case for PREVIEW to nudge the user to contribute more to the conversation when needed, in addition to

nudging them when a message came across as blunt, *"the app could prompt me to think about how I can continue the conversation..."*. Moreover, P4 argued that PREVIEW should be capable of identifying messages that are not inherently rude but may become rude if done repeatedly. They stated, *"It's challenging when actions don't follow a strict rule, and only become rude with repetition. For example, the PREVIEW could direct me to suggest another genre to Ben, which would make for an even better message than asking Ben to pick another genre, especially since I've already said no [to the genre he suggested] like three times"*. Additionally, P5 proposed it would be useful to have PREVIEW triggered for instances where their message came across as sarcastic to *"catch instances where you are trying not to sound sarcastic"* as *"this definitely happened before"* with them. P7 and P8 noted that their inclination towards *"lateral thinking"* and *"jumping between topics"* sometimes led to others struggling to grasp the connection between their messages. They suggested PREVIEW could proactively nudge users to stay focused on the topic at hand in such instances.

Tailoring PREVIEW for Diverse Age Groups. As a parent of autistic kids, P4 envisioned utilizing PREVIEW to teach their children written communication skills. They contended that children of different age levels might require varying levels of explanations, *"I think about how I talk to my 5-year-old autistic kid versus my 15-year-old [real age not disclosed to preserve anonymity] autistic kid, and how I explain things. People with different levels of experience will need different levels of instruction. So, if you have someone who has a lot of meta-cognitive, purpose-built social skills, or someone who doesn't have many of those skills, they might need different levels of explicit explanation. That might be something valuable to customize [with a slider]"*. In their opinion, more detailed feedback could entail precisely specifying the dependency between certain words/phrases and the recipient's reaction, *"I would definitely need to explain to the 5-year-old why someone might perceive a message as blunt or dismissive or whatever. For example, my feedback could include 'the message "horror is for kids" can be problematic because they [the receiver] don't want to be seen as a child, especially if they're an adult'. The extra explanation would be obnoxious to somebody who has already learnt that"*. P1 echoed with these suggestions.

Personalizing Suggestions. P2, P3, P4, and P8 stressed the importance of tailoring the suggested alternate messages to fit their individual writing styles, preferences, and interests. P4 suggested a simple strategy to enhance personalization, proposing that, in addition to offering new message suggestions, SUGGEST should also provide specific guidance on ways to improve the existing message. They saw this feature as a natural extension of SUGGEST seamlessly integrating with PREVIEW. They elaborated, *"it could provide insights like: You might be perceived as dismissive and judgmental of Ben's preferences. A better message could be 'I'm not really into horror films' and then suggesting a genre that you do like."* In their opinion, this could make room for personalization without the AI having to access their personal data or imposing a rigid directive that might not work well for all users, *"how does the computer know what one likes without being connected to their data, which a lot of people might not be excited about?"*. In addition, P8 suggested having a calibration process *"[for the application to] understand me a little bit more"* by *"figuring out what my tone normally is"*.

6 DISCUSSION

In this section, we delve into the design and practical implications of our study, explore future directions, and discuss our limitations.

6.1 Balancing Personalization and Privacy

Participants highlighted the need for improved personalization by adjusting flagging sensitivity, tailoring feedback to user abilities, and matching suggestions to writing styles, alongside concerns that personalization might require

extensive collection of user data. It is important to note that different levels of personalization require varying degrees of user data. Adapting to a user’s writing style in a certain conversation involves analyzing how they communicate within that conversation [49]. Conversely, providing highly personalized message suggestions based on specific interests requires the system to know about users beyond the content of a single conversation [50]. Hence, it is crucial to ask a) with access to ‘just enough information’ about users, can we achieve the required level of personalization, and b) what constitutes ‘just enough information’. In the context of SUGGEST, one strategy is to provide ‘guidance’ or ‘advice’ rather than suggesting alternative messages as replacements. This allows users to personalize their message as well as receive help on how to write and what kind of content to include (or not), without needing to reveal personal data beyond the immediate context of the conversation. Personalization is crucial, yet our findings also indicate that giving users too much to manage—such as overly frequent underlining of phrases—can be overwhelming. Therefore, a key aspect of inculcating personalization into systems lies in offering users control over customizable knobs without over-burdening them [51].

6.2 Toward Trustworthy User Interfaces

Recall that participants were hesitant to trust the system too much, knowing it may not always be correct. They feared that using the system for longer periods could lead them to rely on it even in instances where it was wrong. In the context of providing social support, particularly through subjective interpretations and judgments, being strictly right or wrong is challenging as the connection between writing style and intent can be unclear depending on context and individual differences [52]. Our findings underscore the importance of clearly and transparently communicating this uncertainty to the user, which is inherent to judgements of this nature, particularly when AI is making the judgments. Effectively utilizing user interfaces might be one way to address this [53]. Visual indicators of the AI’s confidence in its output, or using language that suggests possibility (‘could’, ‘might’) rather than certainty (‘will’, ‘must’), can remind users that the AI may not always be correct and encourage them to trust their own instincts.

6.3 Beyond Neurodivergent Users

Drawing inspiration from the double empathy problem [23], we advocate for measures that encourage neurotypical individuals to also contribute to improving communication. P4 and P7 expressed a strong desire for such measures too. For P4, it would be *“interesting to see an app that goes the other way around - rewriting messages for neurotypicals to incorporate direct language.”* P7 echoed these sentiments, expressing, *“They [neurotypical individuals] sort of need to meet me halfway!”* Such an approach could involve deploying a version of the TwIPS prototype on *both* ends of chatting applications for *all* users, whether they identified as neurodivergent or not. An autistic user could receive help from this prototype with interpreting nuanced language and emojis. The same prototype could help a neurotypical user understand the unique writing style of their autistic peer, explaining that a brief reply does not necessarily signal disinterest. This could also extend to interactions among neurotypical users, considering emotional expression and interpretation in text messages, although not to the same degree as autistic users, is challenging for a large proportion of all users [54, 55]. In this way, the prototype could provide feedback to *any* user based on the specific communication challenges they face and the writing style of the person they are interacting with, eliminating the need to distinguish between neurodivergent and neurotypical users. Realizing this vision requires accessibility researchers to engage with neurotypical individuals, exploring their perceptions and interactions with neurodivergent individuals, and ultimately to evaluate prototypes collectively with all users involved. [56]. Given communication is fundamentally collaborative, it

would be interesting for researchers to explore how double empathy can serve as a design framework to extend this approach to other modes of digital communication.

6.4 Combining AI-based Simulations with Real-world Interactions

TwIPS acted as both a learning tool and a safeguard. For example, participants expressed PREVIEW not only helped them develop a mental model of how their words might be perceived as rude, dismissive, or offensive by others (like a learning tool), but also prevented them from coming across as such (like a safeguard). AI-aided simulations together with AI-assistance - similar to participants' interaction with Ben's AI-persona in phase 2 - can provide an environment to learn, and real-time AI-assistance during real-world interactions can serve as a safeguard. However, combining AI-aided simulations with real-world interactions could create a more long-lasting, personalized and dynamic tool. Different AI-personas could allow autistic individuals to engage with different kinds of conversational partners and scenarios in a controlled environment, akin to past AR-based simulations that exposed users to different physical environments or social stories [57]. Conversely, assistance in real-world interactions could help users mitigate challenges in situations involving complex and varied stakes, and enhance learning in real-world settings which may differ from simulations. Together, the simulations and real-world interactions form a symbiotic relationship, where real-world interactions help inform the design of specific simulation strategies while simulations inform the level of assistance needed and what to focus on during real-world interactions. It would be useful for future researchers to explore how to best leverage this symbiotic relationship within a single, autonomous system.

6.5 Practical Implications and Lessons Learnt

Our findings show TwIPS can add value to texting platforms, dating applications, and social media sites that support text-based communication. Popular platforms like Meta's WhatsApp already support generative AI-based bots for open-ended QnA [58] and possess the technical infrastructure needed for widespread AI-adoption. This existing infrastructure, combined with the fact that TwIPS was designed with the layout of standard chatting applications in mind, makes them well-suited for incorporating TwIPS' features. However, any integration would need to be done in a privacy-preserving manner [59]. While there are benefits to deploying it on scale ourselves, such as control over functionality and design, and the opportunity to conduct longitudinal user studies with more participants, practical constraints such as cost pose a significant feasibility challenge for academic researchers. Cost to run the LLM was a major contributor to our expense, which varies with the length of the input and output of each LLM call as well as model quality, which depends on model size [60] and training data quality [61]. We fed the complete conversation history to GPT4 with each call, causing the input length to increase substantially. Employing a cheaper model [62] or retrieval augmented generation techniques [63] to extract relevant portions of history could shorten the input length and thus lower cost. In addition, we observed that one LLM does not need to perform all tasks. Given the variety of models available with different costs and quality, strategically allocating advanced, expensive models for complex tasks, and choosing affordable, less sophisticated models for other use-cases can significantly reduce cost. In the context of TwIPS, a complex task might involve using PREVIEW for a conversation with a potential date as opposed to a casual chat with a friend, or utilizing INTERPRET for explaining a hyper-local phrase unique to a conversation rather than a well-known idiom.

6.6 Limitations

There are a number of limitations of our study. Recruiting participants solely from a university setting restricts the generalizability of our findings to the broader autistic community, due to a lack of diversity in age, background, and education. While the data from our participant pool showed repeated themes, expanding it to include a more diverse demographic might uncover additional themes. In both phases of the user study, participants engaged with an imaginary character. Participants may have made varying assumptions about their relationship dynamics with Ben, leading to differences in their interactions and responses. While keeping the complexity of this setup minimal, we made maximum effort to provide all essential details of the setup to participants. Lastly, the in-lab setting of our study may not fully replicate the nuances and dynamics of real-life texting, which typically involves more complex and varied stakes.

7 CONCLUSION

We investigated how autistic individuals use language for self-expression and interpretation in instant messaging, and explored the potential of LLMs for enhancing their messaging experience. We prototyped TwIPS, a novel chatting interface, and evaluated it with 8 autistic participants in an in-lab setting, showing that it enabled a convenient way for participants to seek clarifications, provided a better alternative to tone indicators, and facilitated constructive reflection on writing technique and style. We discussed considerations around balancing user-autonomy alongside AI-mediation, appropriating trust levels in AI systems, and designing interventions that distribute responsibility for reducing communication breakdowns more equitably across all users, instead of placing it solely on autistic users. In the future, we plan to conduct studies specifically with neurotypical users to explore how they can better understand and interact with autistic individuals, and eventually with both users together. This study is the first step in that direction.

REFERENCES

- [1] American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders: DSM-5*. American Psychiatric Association, Arlington, VA, 5th edition, 2013.
- [2] Enzo Grossi, Elisa Caminada, Michela Goffredo, Beatrice Vescovo, Tristana Castrignano, Daniele Piscitelli, Giulio Valagussa, Marco Franceschini, and Franco Vanzulli. Patterns of restricted and repetitive behaviors in autism spectrum disorders: A cross-sectional video recording study. preliminary report, May 2021.
- [3] Williams AR Maenner MJ, Warren Z et al. Prevalence and characteristics of autism spectrum disorder among children aged 8 years — autism and developmental disabilities monitoring network, 11 sites, united states, 2020. *Morbidity and Mortality Weekly Report*, 72(SS-2):1–14, 2023.
- [4] Philippa L Howard and Felicity Sedgewick. ‘anything but the phone!’: Communication mode preferences in the autism community. *Autism*, 25(8):2265–2278, Jun 2021.
- [5] Christina Nicolaidis, Dora M Raymaker, Elesia Ashkenazy, Katherine E McDonald, Sebastian Dern, Amelia EV Baggs, Steven K Kapp, Michael Weiner, and W Cody Boisclair. “respect the way i need to communicate with you”: Healthcare experiences of adults on the autism spectrum. *Autism*, 19(7):824–831, Apr 2015.
- [6] Belén Barros Pena, Nelya Koteyko, Martine Van Driel, Andrea Delgado, and John Vines. “my perfect platform would be telepathy” - reimagining the design of social media with autistic adults. *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, Apr 2023.
- [7] Xinru Page, Andrew Capener, Spring Cullen, Tao Wang, Monica Garfield, and Pamela J. Wisniewski. Perceiving affordances differently: The unintended consequences when young autistic adults engage with social media. *CHI Conference on Human Factors in Computing Systems*, Apr 2022.
- [8] Ryan Anthony Jalova De Belen, Tomasz Bednarz, and Arcot Sowmya. Eyexplain autism: Interactive system for eye tracking data analysis and deep neural network interpretation for autism spectrum disorder diagnosis, May 2021.
- [9] Muhammad Arshad, Muhammad Sarwar, Meher Fatima Zaidi, and Suleman Shahid. East: Early autism screening tool for preschoolers, Apr 2020.
- [10] Carlos Duarte, Luís Carriço, David Costa, D. C. Costa, André O. Falcão, and Luís Tavares. Welcoming gesture recognition into autism therapy, Apr 2014.
- [11] Minkyong Jeong, YoungTae Kim, Dongsun Yim, Yeon Seokjeong, Seokwoo Song, and John Kim. Lexical representation of emotions for high functioning autism(hfa) via emotional story intervention using smart media, Apr 2015.
- [12] Andrea Tartaro. Authorable virtual peers for children with autism, Apr 2007.

- [13] Peter Washington, Catalin Voss, Nick Haber, Serena Tanaka, Jena Daniels, Carl Feinstein, Terry Winograd, and Dennis P. Wall. A wearable social interaction aid for children with autism, May 2016.
- [14] Will Simm, Maria Angela Ferrario, Adrian Gradinar, Marcia Tavares Smith, Stephen Forshaw, Ian Smith, and Jon Whittle. Anxiety and autism, May 2016.
- [15] Bogwan Kim, Sung-In Kim, Sangwon Park, Hee Jeong Yoo, Hwajung Hong, and Kyungsik Han. Routineaid: Externalizing key design elements to support daily routines of individuals with autism, Apr 2023.
- [16] Ouriel Grynspan, Jean-Claude Martin, and Jacqueline Nadel. Human computer interfaces for autism, Apr 2005.
- [17] Amon Rapp, Federica Cena, Guido Boella, Alessio Antonini, Alessia Calafiore, Stefania Buccoliero, Maurizio Tirassa, Roberto Keller, Romina Castaldo, and Stefania Brighenti. Interactive urban maps for people with autism spectrum disorder, May 2017.
- [18] Kay Kender and Katta Spiel. Banal autistic social media: A found footage autoethnography. In *Proceedings of the 25th International ACM SIGACCESS Conference on Computers and Accessibility*, ASSETS '23, New York, NY, USA, 2023. Association for Computing Machinery.
- [19] Partha Pratim Ray. Chatgpt: A comprehensive review on background, applications, key challenges, bias, ethics, limitations and future scope. *Internet of Things and Cyber-Physical Systems*, 3:121–154, 2023.
- [20] Steven M. Goodman, Erin Buehler, Patrick Clary, Andy Coenen, Aaron Donsbach, Tiffanie N. Horne, Michal Lahav, Robert MacDonald, Rain Breaw Michaels, Ajit Narayanan, Mahima Pushkarna, Joel Riley, Alex Santana, Lei Shi, Rachel Sweeney, Phil Weaver, Ann Yuan, and Meredith Ringel Morris. Lampost: Design and evaluation of an ai-assisted email writing prototype for adults with dyslexia. *Proceedings of the 24th International ACM SIGACCESS Conference on Computers and Accessibility*, Oct 2022.
- [21] JiWoong (Joon) Jang, Sanika Moharana, Patrick Carrington, and Andrew Begel. “it’s the only thing i can trust”: Envisioning large language model use by autistic workers for communication assistance. *Proceedings of the CHI Conference on Human Factors in Computing Systems (CHI '24)*, May 2024.
- [22] OpenAI, :, and Josh Achiam et. al. Gpt-4 technical report, 2023.
- [23] Damian E.M. Milton. On the ontological status of autism: the ‘double empathy problem’. *Disability & Society*, 27(6):883–887, 2012.
- [24] Penny Benford and P Standen. The internet: a comfortable communication medium for people with asperger syndrome (as) and high functioning autism (hfa)? *Journal of Assistive Technologies*, 3(2):44–53, Jul 2009.
- [25] Kristen Gillespie-Lynch, Steven K. Kapp, Christina Shane-Simpson, David Shane Smith, and Ted Hutman. Intersections between the autism spectrum and the internet: Perceived benefits and preferred functions of computer-mediated communication. *Intellectual and Developmental Disabilities*, 52(6):456–469, Dec 2014.
- [26] Moira Burke, Robert Kraut, and Diane Williams. Social use of computer-mediated communication by adults on the autism spectrum. *Proceedings of the 2010 ACM conference on Computer supported cooperative work*, Feb 2010.
- [27] Philip Quinn and Shumin Zhai. A cost-benefit study of text entry suggestion interaction. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, pages 83–88, New York, NY, 2016.
- [28] Matthew Henderson, Rami Al-Rfou, Brian Strope, Yun-Hsuan Sung, László Lukács, Ruiqi Guo, Sanjiv Kumar, Balint Miklos, and Ray Kurzweil. Efficient natural language response suggestion for smart reply. *ArXiv*, abs/1705.00652, 2017.
- [29] Jacob Devlin, Ming-Wei Chang, Kenton Lee, and Kristina Toutanova. Bert: Pre-training of deep bidirectional transformers for language understanding, 2019.
- [30] Ashish Vaswani, Noam Shazeer, Niki Parmar, Jakob Uszkoreit, Llion Jones, Aidan N. Gomez, Lukasz Kaiser, and Illia Polosukhin. Attention is all you need, 2023.
- [31] Liye Fu, Benjamin Newman, Maurice Jakesch, and Sarah Kreps. Comparing sentence-level suggestions to message-level suggestions in ai-mediated communication. *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, Apr 2023.
- [32] Andy Coenen, Luke Davis, Daphne Ippolito, Emily Reif, and Ann Yuan. Wordcraft: a human-ai collaborative editor for story writing, 2021.
- [33] Gabriel Lima, Nina Grgić-Hlača, and Meeyoung Cha. Human perceptions on moral responsibility of ai: A case study in ai-assisted bail decision-making. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, CHI '21, New York, NY, USA, 2021. Association for Computing Machinery.
- [34] Nur Yildirim, Mahima Pushkarna, Nitesh Goyal, Martin Wattenberg, and Fernanda Viégas. Investigating how practitioners use human-ai guidelines: A case study on the people + ai guidebook. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, CHI '23, New York, NY, USA, 2023. Association for Computing Machinery.
- [35] Justin D. Weisz, Michael Muller, Jessica He, and Stephanie Houde. Toward general design principles for generative ai applications, Jan 2023.
- [36] Su Lin Blodgett, Q. Vera Liao, Alexandra Olteanu, Rada Mihalcea, Michael Muller, Morgan Klaus Scheuerman, Chenhao Tan, and Qian Yang. Responsible language technologies: Foreseeing and mitigating harms. In *Extended Abstracts of the 2022 CHI Conference on Human Factors in Computing Systems*, CHI EA '22, New York, NY, USA, 2022. Association for Computing Machinery.
- [37] Jungin Park, Gahyeon Bae, Jueon Park, Seo Kyoung Park, Yeon Soo Kim, and Sangsu Lee. Aedle: Designing drama therapy interface for improving pragmatic language skills of children with autism spectrum disorder using ar. *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems*, Apr 2023.
- [38] LouAnne Boyd, Saumya Gupta, Sagar B. Vikmani, Carlos M. Gutiérrez, Jing-Fang Yang, Erik Linstead, and Gillian R. Hayes. vrsocial, Apr 2018.
- [39] Laura Tarantino, Margherita Attanasio, Tania Di Mascio, Giovanni De Gasperis, Marco Valenti, and Monica Mazza. On the evaluation of engagement in immersive applications when users are on the autism spectrum. *Sensors*, 23(4):2192, Feb 2023.

- [40] Peter Washington, Catalin Voss, Aaron Kline, Nick Haber, Jena Daniels, Azar Fazel, Titas De, Carl Feinstein, Terry Winograd, and Dennis Wall. Superpowerglass. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, 1(3):1–22, Sep 2017.
- [41] Geraldine Dawson and Karen Burner. Behavioral interventions in children and adolescents with autism spectrum disorder. *Current Opinion in Pediatrics*, 23(6):616–620, Dec 2011.
- [42] Tooba Ahsen, Christina Yu, Amanda O’Brien, Ralf W Schlosser, Howard C. Shane, Dylan Oesch-Emmel, Eileen T. Crehan, and Fahad Dogar. Designing a customizable picture-based augmented reality application for therapists and educational professionals working in autistic contexts. In *Proceedings of the 24th International ACM SIGACCESS Conference on Computers and Accessibility*, ASSETS ’22, New York, NY, USA, 2022. Association for Computing Machinery.
- [43] Mrbullwinkle. What’s new in azure openai service? - azure ai services, Apr 2024.
- [44] Brown et. al. Language models are few-shot learners, 2020.
- [45] Prompt engineering.
- [46] B. S. Aylward, D. E. Gal-Szabo, and S. Taraman. Racial, ethnic, and sociodemographic disparities in diagnosis of children with autism spectrum disorder. *Journal of Developmental and Behavioral Pediatrics*, 42(8):682–689, Oct-Nov 2021.
- [47] Emani Dotch, Jazette Johnson, Rebecca W. Black, and Gillian R Hayes. Understanding noise sensitivity through interactions in two online autism forums. *The 25th International ACM SIGACCESS Conference on Computers and Accessibility*, Oct 2023.
- [48] Virginia Braun and Victoria Clarke. Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2):77–101, Jan 2006.
- [49] Yeh et. al. Ghostwriter: Augmenting collaborative human-ai writing experiences through personalization and agency, 2024.
- [50] Deepjyoti Roy and Mala Dutta. A systematic review and research perspective on recommender systems. *Journal of Big Data*, 9(1), May 2022.
- [51] Sarah Hui and Swee See. Enhancing user experience through customisation of ui design. *Procedia Manufacturing*, 3:1932–1937, 12 2015.
- [52] Thomas Holtgraves. Text messaging, personality, and the social context. *Journal of Research in Personality*, 45(1):92–99, 2011.
- [53] Cheng Chen and S. Shyam Sundar. Is this ai trained on credible data? the effects of labeling quality and performance bias on user trust. *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, Apr 2023.
- [54] Hannah Miller, Daniel Kluver, Jacob Thebault-Spieker, Loren Terveen, and Brent Hecht. Understanding emoji ambiguity in context: The role of text in emoji-related miscommunication. 05 2017.
- [55] Lynne Kelly and Aimee E. Miller-Ott. Perceived miscommunication in friends’ and romantic partners’ texted conversations. *Southern Communication Journal*, 83(4):267–280, 2018.
- [56] Brooke Ayers Morris, Hayati Havlucu, Alison Oldfield, and Oussama Metatla. Double empathy as a lens to understand the design space for inclusive social play between autistic and neurotypical children. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems*, CHI EA ’23, New York, NY, USA, 2023. Association for Computing Machinery.
- [57] Tooba Ahsen. *Exploring the Design and Development of Augmented Reality Applications for Challenging Scenarios Using User-Driven Design Approaches*. PhD thesis, 2023. Copyright - Database copyright ProQuest LLC; ProQuest does not claim copyright in the individual underlying works; Last updated - 2023-03-10.
- [58] Facebook Company and Meta. Introducing new ai experiences across our family of apps and devices, Jan 2024.
- [59] Yiming Wang, Yu Lin, Xiaodong Zeng, and Guannan Zhang. Privatelora for efficient privacy preserving llm, 2023.
- [60] Jared Kaplan, Sam McCandlish, Tom Henighan, Tom B. Brown, Benjamin Chess, Rewon Child, Scott Gray, Alec Radford, Jeffrey Wu, and Dario Amodei. Scaling laws for neural language models, 2020.
- [61] Tianxing He, Shengcheng Yu, Ziyuan Wang, Jieqiong Li, and Zhenyu Chen. From data quality to model quality: an exploratory study on deep learning, 2019.
- [62] Touvron et al. Llama 2: Open foundation and fine-tuned chat models, 2023.
- [63] Patrick S. H. Lewis, Ethan Perez, Aleksandra Piktus, Fabio Petroni, Vladimir Karpukhin, Naman Goyal, Heinrich Küttler, Mike Lewis, Wen-tau Yih, Tim Rocktäschel, Sebastian Riedel, and Douwe Kiela. Retrieval-augmented generation for knowledge-intensive NLP tasks. *CoRR*, abs/2005.11401, 2020.

A PROMPT TEMPLATES AND FLOWS

Figures 5, 6 and 7 show the prompt templates and flows used within TwIPS.

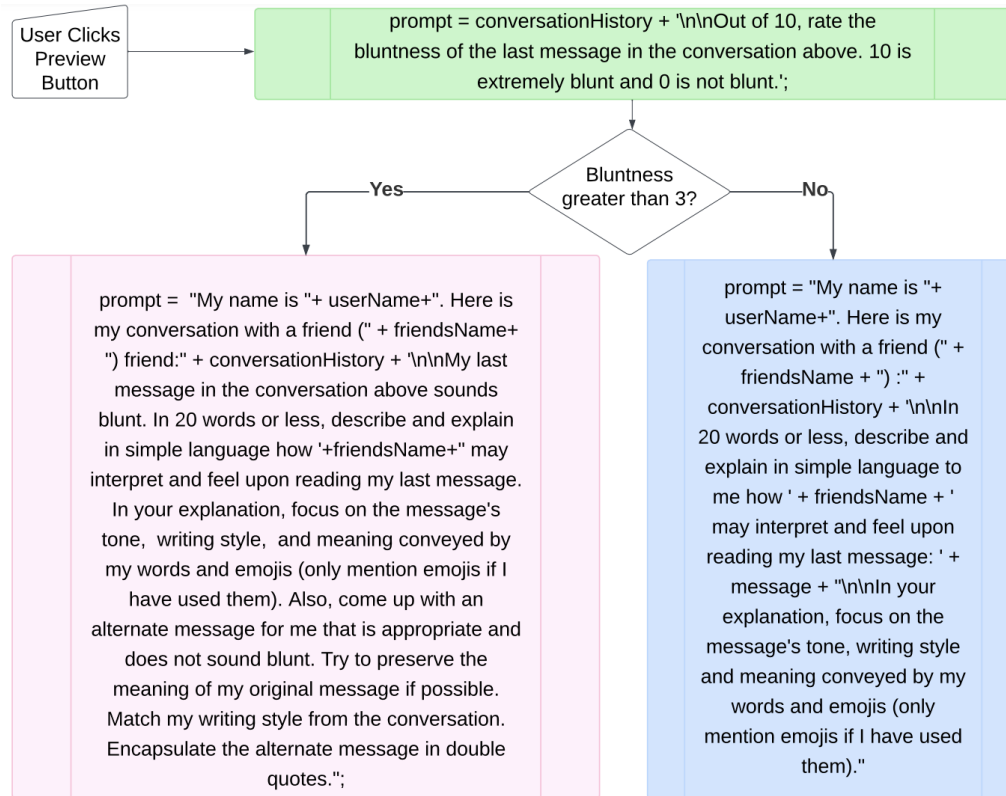


Fig. 5. Prompt template and flow for clicking on 'Preview Button'.

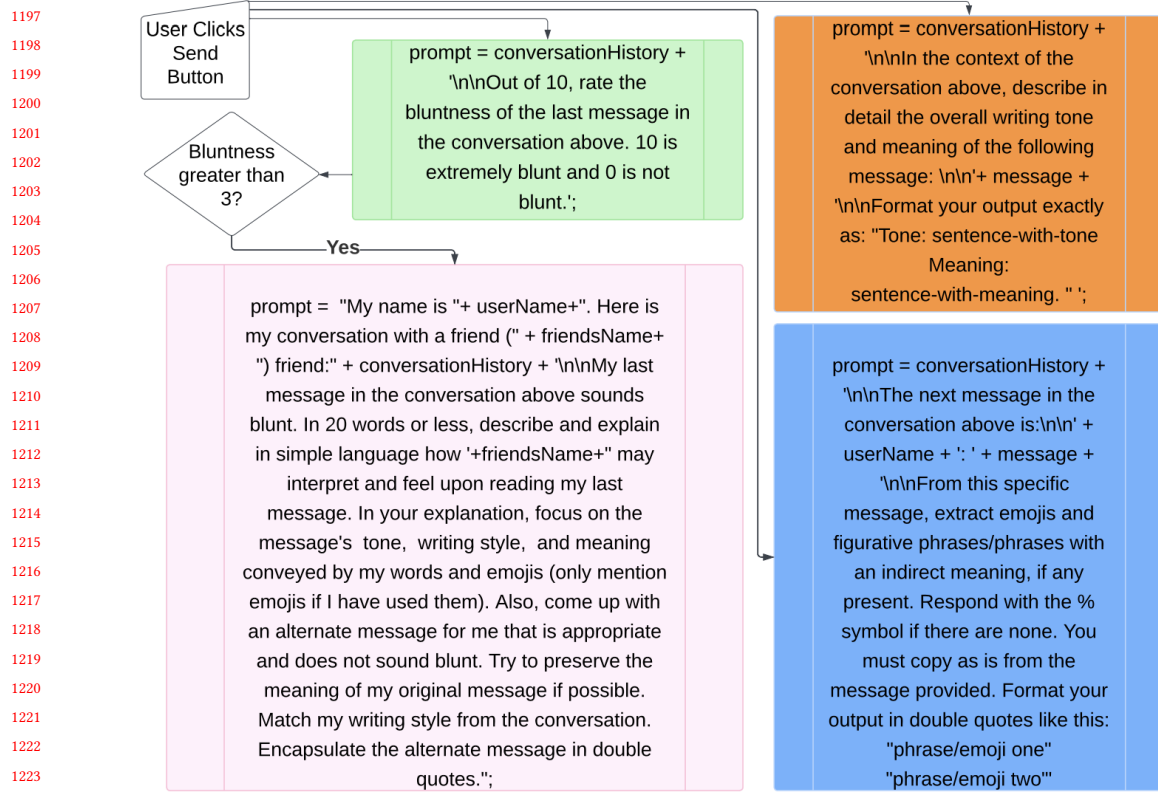


Fig. 6. Prompt template and flow for clicking on 'Send' Button.

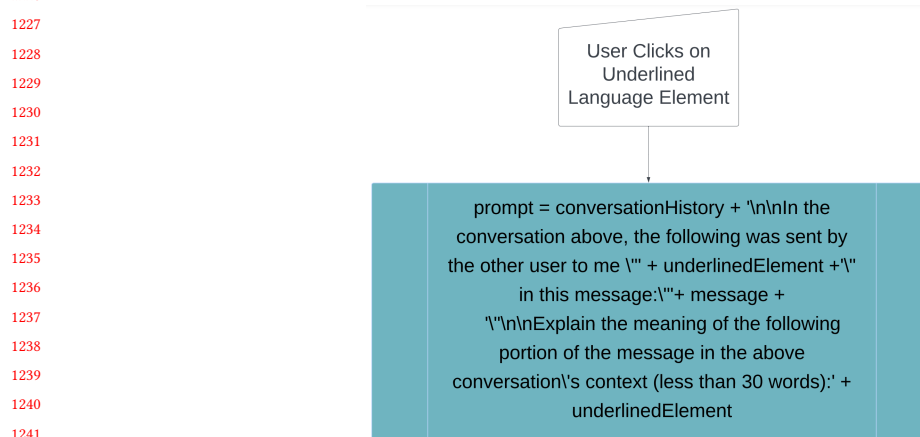


Fig. 7. Prompt template and flow for clicking on an underlined ambiguous language element.

B CONVERSATIONAL SCRIPT USED IN PHASE 1

The conversational script used in phase 1 of the user study is provided below.

Ben: hey, did you hear? it's Jack's birthday next week!

Model Response: yeap, i know!

Ben: well, I thought we could plan a surprise party for him.

Model Response: hmm.. is a party our only option?

Ben: nope, we can do something else too. like a movie night at the theater.

Model Response: we could do that, yes!

Ben: awesome! we can pick a movie that everyone likes. Are you into horror films?

Model Response: no... horror is for kids who want to be scared

Ben: LOL. sometimes a good horror flick can be a fun experience, even for grown ups.

Model Response: if it will make jack happy, i am ok with it i guess

Ben: by the way, have you thought about what kind of birthday present we should get him?

Model Response: can we just get him a gift card?

Ben: it might be nice to show him that we put some thought into his bday present. it's his birthday, and he's our friend!!

Model Response: yeah, you are actually right. we can go to the store tomorrow to see what we can get.

Ben: we can split costs. what is your budget?

Model Response: I do not want to spend too much.

Ben: thats fine... There is a store at a 20 min walk from the office. We can go there.

Model Response: alright, I'll put on my joggers then haha

Ben: LOL! Should we invite others too?

Model Response: umm... is that necessary?

Ben: nope, not really

Model Response: so let's not, I guess.

Ben: why though?

Model Response: coordinating with others is a hassle

Ben: Lol okay if you say so! see you in class tomorrow then.

Model Response: oki! catch you later :)