Tone Indicators: Designing Accessible CMC Cues for Neurodiverse Users

AMY WEI XIAO*†, Brown University, USA
ZAINAB IFTIKHAR*, Brown University, USA
JEFF HUANG, Brown University, USA

As messaging becomes increasingly salient to social connection and well-being, there exists a gap in understanding and support for neurodivergent users who may struggle with interpreting tone in computer-mediated communication (CMC). We look to existing accessibility practices among neurodivergent communities to thus propose a system of alternative cues that explicitly flag tone and intent, in hopes of better scaffolding neurodiverse communication styles. Through a mixed-method study of conversational pairs (N=18), we assessed the impact of these tone indicators on participants' experiences of synchronous messaging and social connection, interpreting our findings in the context of disability-focused design for messaging interfaces. We found that these alternative cues lowered the overall cognitive load of live tone interpretation for neurodivergent users, enabling a greater sense of confidence and control over self-presentation. In turn, participants reported more positive and in-depth conversations with their partners. We further observed that some participants typed more slowly, wrote longer messages, and used additional communication cues, like emojis and text stylization, concurrently. Participants' use and feedback on this tool also illuminated social context and collaboration's role in cue ambiguity. Our work subsequently suggests future research and design directions on supporting communicative accessibility via the intentional design of alternative cue systems and co-customization.

CCS Concepts: • **Human-centered computing → Empirical studies in HCI**; **Empirical studies in collaborative and social computing**; **Accessibility systems and tools**; *Accessibility theory, concepts and paradigms*.

Additional Key Words and Phrases: communication; tone indicators; neurodiversity; accessibility; computer-mediated communication; CMC cues

ACM Reference Format:
Amy Wei Xiao, Zainab Iftikhar, and Jeff Huang. 2025. **Tone Indicators: Designing Accessible CMC Cues for Neurodiverse Users** . *Proc. ACM Hum.-Comput. Interact.* 9, 7, Article 496 (November 2025), 20 pages. https://doi.org/10.1145/3757677

1 INTRODUCTION

Computer-mediated communication (CMC) has become an important avenue for neurodivergent individuals to seek connection and community. The structured nature of online spaces offers greater clarity and control for those who struggle with interpreting non-verbal cues otherwise present in face-to-face interactions [3, 10, 11, 26, 27, 43]. However, the growing complex features in CMC have introduced new constructions of social cues—both meta- and para-textual—that recreate many of the similar challenges neurodivergent individuals have faced in in-person interactions [11, 24, 44]. At the

*Equal contribution
†Work completed while at Brown University

Authors' addresses: Amy Wei Xiao, amy_xiao@alumni.brown.edu, Brown University, USA; Zainab Iftikhar, zainab_iftikhar@brown.edu, Brown University, USA; Jeff Huang, jeff_huang@brown.edu, Brown University, USA.

ACM 2573-0142/2025/11-ART496
https://doi.org/10.1145/3757677

same time, current technical work in CMC research continues to advance new features and modalities of these virtual cues [1, 26]. Previous participatory work highlights the need to intentionally design for communicative accessibility in social technology to scaffold and support neurodivergent communication styles [30, 44, 48]. This study explores one such accessibility feature by introducing tone indicators as a supplementary cue system in synchronous messaging settings.

Over the last decade, neurodivergent online communities have begun to adopt tone indicators as a paralinguistic cue to communicate the explicit tone or intent of a message, frequently taking the form of an appended /[acronym]. Commonly used indicators include /srs for 'serious', /pos for 'positive', /j for 'joking', and /s for 'sarcasm'; however, a wide variety of indicators have been documented in online communities' forums, including those less obvious like /hj for 'half-joking' [31]. These indicators have been most visible within text-based social media platforms like Discord, Twitter, and Reddit, where high-volume message exchange, limited context information, and in-group knowledge result in a sizable potential for miscommunication [28]. An observational study of tone indicators online has suggested that these indicators have proven valuable for neurodivergent individuals who struggle with gauging intent, enabling them to attain greater clarity regarding a message's meaning when information is otherwise unavailable or inaccessible, as well as more accurately communicate their own emotions [13]. Beyond this observational analysis, however, the design pattern of tone indicators remains relatively unexplored as a potential digital accessibility aid. In fact, research on digital interventions to support adult neurodivergent communication in online spaces is overwhelmingly sparse, despite surveys of autistic adults' computing research priorities finding that communication and social skills were key areas of interest [30]. Meta-reviews of prior computing research further highlight a persistent deficit-based perspective on which neurodivergent communication [2, 16], predicating studies on the assumption that these users should—and fail to—conform to a neurotypical baseline because of personal deficits. This research thus aims to explore whether tone indicators, currently a text-based community-driven practice, can be formalized as a system of CMC cues that can be scaled across social technologies and validated empirically, as a tool to effectively support neurodivergent communication styles. Through this study, we seek to additionally contribute a methodological and theoretical framework to future HCI and CSCW work on neurodivergent communication that explicitly utilizes a disability-informed perspective.

This study explores three main research questions:

RQ1: Does the implementation of tone indicators make tone interpretation, intent, and self-presentation more intuitive for neurodivergent users?

RQ2: Does the use of tone indicators contribute to higher conversation quality in text-based synchronous peer discussions?

RQ3: How do neurodivergent users understand the contextual use of tone indicators, especially as compared to other paralinguistic cues?

To address these questions, we developed a chat room with a tone indicator feature that allowed users to explicitly tag the tone of their message via a key prompt, which is then displayed as a distinct visual element (as shown in Figure 4). Then we used a mixed-methods approach by conducting a quantitative analysis of the experimental sessions measuring affectual accuracy, dimensions of conversation quality (i.e., trust, reciprocity, affect, etc.), and engagement, as well as a qualitative analysis of participants' experimental experiences with tone indicators and other CMC cues.

To evaluate these applications while maintaining a focus on neurodivergent communication dynamics, we recruited 18 neurodivergent participants of whom identified that reading tone online is difficult. These subjects participated in four, synchronous peer discussion sessions in which they were given a prompt designed to induce more intensive and multifaceted conversation. Two of these four sessions were randomized with a *tone indicator* condition, where participants were given a tutorial of and asked to use the tone indicators feature during the session. Data on these sessions were

collected through systems data, affectual assessments of sent and received messages on a 5-point visual scale, and a post-session questionnaire. Post-experiment, semi-structured interviews were also conducted with participants, exploring their experiences with CMC cues, neurodivergence, and tone indicators before and during the experimental sessions.

Our analysis found that tone indicators lowered the overall cognitive load of tone interpretation for neurodivergent users, enabling a greater sense of confidence and control over self-presentation. In turn, participants reported more positive and in-depth conversations, additionally highlighting the various impacts of social context on the utility and use of tone indicators.

2 BACKGROUND AND RELATED WORK

This section explores prior work related to the intersection of neurodivergence, social technology, and communicative accessibility in social interaction design.

2.1 Neurodivergent Users and Social Technology

Prior studies highlight the importance of social technology and online communities for neurodivergent adults, finding that many prefer digital channels to seek connectedness and have overall more social satisfaction doing so [11, 35, 43]. In particular, the more structured nature of CMC enables greater clarity and control to those who face challenges in picking up non-verbal social cues within face-to-face interactions, potentially reducing social burnout and facilitating connections with others [3, 11, 27, 36]. CMC can thus be beneficial in reducing social burnout and facilitating connections for neurodivergent users [27, 36].

However, evolutions in CMC features (gifs, emojis, text stylization, etc.) and their context-specific social meaning have recreated many of the same challenges to interpreting social cues as in-person interactions, raising barriers to assess 'appropriate' levels of trust or disclosure [11, 44]. Indeed, while many studies have observed the ability of emojis to improve connection between users, allowing for subtle self-disclosure and insights into users' emotional states, they also highlighted a complex and ever-evolving set of social rules that surround their use [1, 11, 21, 42, 45, 47]. As a result, while neurodivergent users may prefer CMC to seek out and maintain social networks, confusing CMC social cues and delays in informative feedback result in significant challenges in translating online acquaintances into lasting friendships and feed into feelings of disconnect [3, 11, 19, 44].

On the other hand, social interaction design presents a valuable opportunity to address these challenges and provide better experiences for neurodivergent users in CMC. One study of neurodiverse dyads highlights the importance of setting common ground between users, outlining several key directions to support neurodiverse communication dynamics, namely to *scaffold the conversation as a whole, support multi-modality, support the users prior to and after conversations,* and *make the state of the conversation visible* [48]. In line with this guidance, prior work has explored various means to enable clarity into conversational partners' emotions. SayWAT, for instance, explores wearable assistive technology to provide live feedback to users during face-to-face interactions [5], while Kodi is a mobile virtual conversational agent that aims to facilitate communication between autistic children and their caretakers during times of distress [18]. Another study had taken a more speculative approach, using participatory methods to speculate on the potential for image-based emotion translation and artifact curation during online communication [49].

However, current research aimed at supporting neurodiverse experiences *within CMC systems* remains quite limited, despite parallel work showing that the existing design of many social technologies is insufficient for fostering inclusive participation among autistic adults [30, 44]. Our work thus seeks to explore means of structurally supporting communicative accessibility in the design of messaging interfaces.

2.2 Neurodiversity as a Framework for Social Connection and Engagement

Traditional interventions for autism and other disabilities that affect social skills are often grounded in the Theory of Mind framework [2, 16]. This approach emphasizes the presumed deficits in social cognition, suggesting that neurodivergent individuals are inherently unable to understand the mental states of others [17]. As a result, these interventions focus on prioritizing strategies that teach neurodivergent individuals to mimic neurotypical social behaviors, often focusing on "masking" or compensatory techniques rather than addressing underlying environmental or communicative barriers [14, 16, 39]. Similarly, computing research commonly presumes this deficit-based perspective, designing solutions and technologies that aim to "fix users" instead of exploring how technology can be adapted to meet the needs of neurodivergent users [20, 30]. Research indicates that these approaches, however, can lead to exhaustion, depression, and poorer mental health outcomes overall [12, 39].

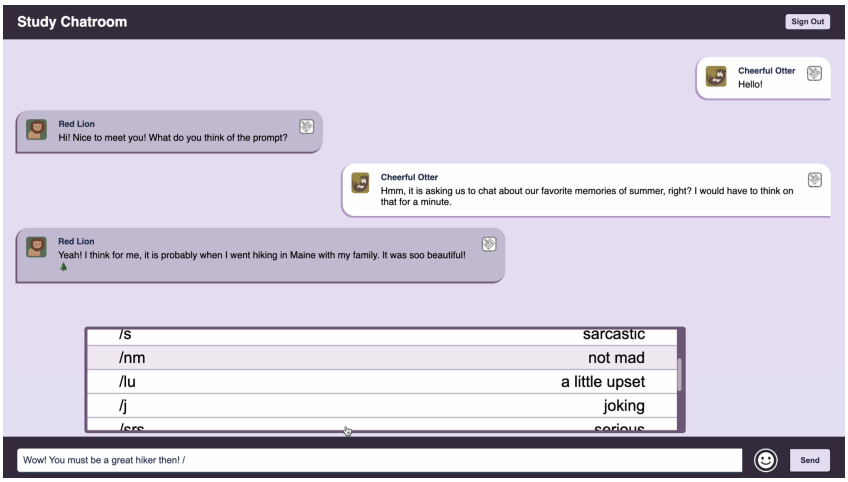
In contrast, disability advocates call for a neurodiverse understanding of social connection and engagement [20, 41]. Neurodiversity is a term popularized by Singer [41] that describes neurological pluralism, including conditions such as autism spectrum disorder, attention-deficit hyperactivity disorder, and obsessive-compulsive disorder. This framework aligns with the social model of disability, emphasizing that many of the challenges faced by neurodivergent individuals are rooted in environmental barriers rather than personal deficits [32, 41]. Applying a neurodiversity framework to the examination of assistive communication technology thus necessitates a critical re-evaluation of common conceptions of social engagement. For example, researchers studying intersubjectivity with autistic participants have found that conventional measures of quality conversation do not always apply to neurodivergent individuals [25]. While discussions in this study exhibited fractured interactions with minimal cooperative signaling, further analysis indicated a generous presumption of common ground among participants. This presumption, while resulting in a lack of conversation coherence, also fostered creative and constructive dialogue [25]. As a result, descriptive observations of social engagement, such as equal exchanges of messages, must be explicitly contextualized through the personal assessments and qualitative experiences of neurodivergent participants.

In our research, we specifically adopted this neurodiversity framework, choosing to implement and test a system that builds on user-driven accessibility practices while utilizing a study design that centers self-reporting measures and user insights.

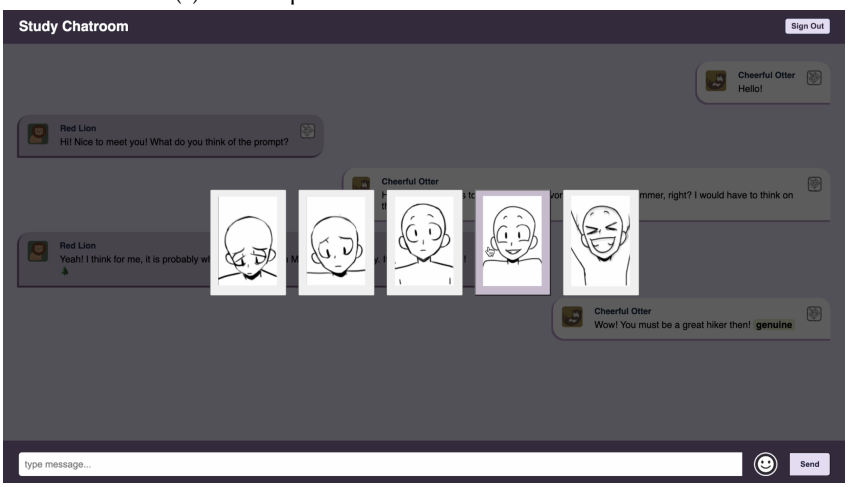
3 METHODS

3.1 Tone Indicator Chat Application

The system for this study utilizes a web-based chat app built using React and Firebase, as well as a mix of open-source and custom components. The chat application consisted of a single chat room per pair that allowed for real-time communication, in which users can use a tone indicator feature. As displayed in figure 1a, the feature allowed users to add a tone indicator by typing "/" and then selecting an indicator from a pop-up window of different tone indicators, or to add an indicator directly by simply typing it or its acronym. To ensure we examine the design proposition of tone indicators as explicit cues and to lower the experiential learning curve, we limited the selection to those most referenced in community-compiled guides (such as 'a guide to tone indicators' [31]), specifically: *genuine, positive, negative, sarcastic, not mad, a little upset, joking, serious, not serious, metaphorically, hyperbole,* and *teasing*. By doing so, we sought to minimize potential user confusion while still providing a strong baseline for evaluating their perceived effectiveness as an accessibility feature. When used, these indicators are then divided into distinct UI components where they are bolded and highlighted for visual accessibility. Data on tone indicator usage (such as the chatroom, specific message, user, and the purpose of the indicator) was stored on a password-protected cloud server.



(a) An example of users' selection of tone indicators



(b) An example of users' affect rating manikin

Fig. 1. Two screenshots of the experimental tone indicator system (right) and built-in visual assessment scales for each message (left).

The chat application has additional features to enable a streamlined data collection of emotional affect assessments, shown in Figure 1b. The feature functions similarly to that of an emoji reaction on iMessage or Discord, where clicking a small checklist icon on the top left of a message will open a selector screen with the aforementioned visual assessment scale. After a user has made a reaction, the aforementioned icon is grayed out. Unlike emoji reactions, their scale selection is stored in the backend API only and is neither visible to them nor their conversation partner. This design choice was intentional to avoid biasing participants when rating their conversation. To focus primarily on text-based communication, users were not able to send photos, videos, or voice memos. However, the platforms supported the use of emojis, as well as any other text-based cues (such as emoticons, nonstandard/multiple punctuation, or other lexical surrogates).

Neurodivergent Identities	# of Participants	% of Participants
Autism	12	66.7
ADHD	4	22.2
OCD	3	16.7
Anxiety/Mood Disorders	3	16.7
Mixed	6	33.3
Gender Identity	**# of Participants**	
Woman/Female	10	55.6
Trans/Nonbinary/Agender	6	33.3
Man/Male	2	11.1
Occupation	**# of Participants**	
Student	14	77.7
Working Professional	4	22.2

Fig. 2. Participant demographics including self-reported neurodivergent identities, gender identity, and occupation.

3.2 Participants

Participants for this study were recruited via public flyers around a university. The eligibility requirements sought individuals between the ages of 18–35 who struggle with tone and self-identify as neurodivergent (defined as those with conditions such as ADHD, autism, anxiety, or otherwise feel that they differ from normative communication, thinking, and or learning styles), and who have access to a computer and internet. These eligibility criteria were selected to gather participants who would be familiar with navigating new technology, have relatively equal conversational dynamics when paired up, and reflect the current audience of the neurodivergent community online. We specifically did not require a medical diagnosis or disclosure of specific disabilities, as the system we are testing is not intended to be a prescribed intervention but rather a feature that users can freely opt to use based on self-identified needs. 18 participants were recruited for this experiment by randomly selecting those who fit the study criteria and expressed interest (Table 2). Participants ranged in age from 18 to 23 years (mean = 20, standard deviation = 2) years of age. Of the 18 participants, 10 participants identified as women/female, 2 identified as men/male, 6 identified as trans, nonbinary, or agender. Additionally, participants reported a diverse array of neurodivergent identities, often intersecting, including autism, ADHD, OCD, depression, and anxiety. Participants had varying prior experience with tone indicators: 5 participants used them actively, 5 used them infrequently, 5 had seen them online, and 3 had never seen them. While we recorded this experience, we did not use it as a factor to preemptively filter out participants.

3.3 Procedure

We conducted a remote study in which participants were paired up randomly based on common availability for four anonymous peer discussions flexibly scheduled across a week. Participants did not know each other prior to being paired up for the study. 30 minutes before each of the sessions began, participants were emailed a short set of instructions for the session, including a tutorial on how to navigate the chatroom, their discussion prompt and chat room link, the post-session survey, and a tutorial on tone indicators and the indicator feature (if applicable). For the four sessions, participants were given a prompt designed to provoke discussion (for example: *"Do you think you can separate the art from the artist? How do you view the balance between artistic freedom and social responsibility?"*) and instructed to have a conversation with their partner as they normally would on the chat app (see Appendix B).These discussion prompts were generated collaboratively by the authors and then

iteratively piloted and edited for further function. At the end of these sessions, both participants were asked to go through their message history and rate the affect of both their own and their partner's messages using a pictorial scale. Participants then filled out a Likert scale on experiences of social engagement on Qualtrics. In two of these four sessions, randomly ordered, session instructions included a short guide to tone indicators and a tutorial on the feature. These instructions were brief and specifically designed to allow participants flexibility in their interpretation of use, encouraging participants to use tone indicators when they saw a reasonable opportunity. These sessions followed the same format as the previous sessions, only now participants were instructed to use tone indicators. Researchers were not in the chatroom and did not monitor the conversation live, but reviewed the chat logs after the conclusion of the session and were available to contact in case of safety concerns or technical issues during the discussion. Given the case that participants did not use indicators during an indicator session, researchers checked in with the participants to clarify whether they were confused about their use or if they saw them as unnecessary, but did not further mandate their use. After all sessions were complete, the participants participated in a semi-structured 20-minute Zoom interview about their prior experiences with text-based communication, their experience with tone indicators within the chat application, and their thoughts on tone indicators as a CMC feature more broadly.

3.4 Measures & Data Analysis

In order to understand neurodivergent participants' holistic experience of communication technology, this study uses a mixed-methods approach to data collection and analysis, conducting quantitative analysis of participant's affective accuracy, affective expressiveness, experiences with six dimensions of conversation quality (*Affect, Depth, Equality, Formality, Immediacy,* and *Trust*)[15], and messaging behavior, as well as a thematic analysis of post-experimental participant interviews using Braun and Clark's (2006, 2019) process [7, 8]. Quantitative data was collected through three main avenues — **visual scale assessments, questionnaires, and system data**. In particular, the visual assessments will be used for both measures of affectual accuracy and affectual expression through a comparison of sender vs. receiver ratings and the magnitude of ratings, respectively. Given the differences in affective perception between neurodivergent and neurotypical populations, this study utilized a visual scale validated with both autistic and non-autistic populations to gather these assessments [34]. Measures of conversation dimensions were then accounted for by a post-session, 5-point Likert questionnaire. Lastly, the semi-structured interview of participant experiences focused on three key questions: experiences with CMC as informed by neurodivergent identities (including prior use of paralinguistic cues and knowledge of tone indicators), influence of tone indicators within the experimental context, and thoughts on tone indicators as a potential CMC feature.

3.4.1 Affect Analysis. The measures of affectual accuracy and expressiveness were assessed using participants' visual scale assessments of messages [34]. These assessments were stored in the database as `sender_reaction` and `receiver_reaction`, of which each message had both. Before any analysis was performed, the chatroom data was imported into a JSON file and pre-processed to check for missing messages and improper assessments. One participant's messages were removed from this dataset as assessments were either missing or only 'neutral'. After this pre-processing, the visual assessments were mapped to an integer scale of -2 to +2. Then, to calculate affectual accuracy, the distance between the sender and receiver rating was calculated by participant and condition. The higher the distance, the more inaccurate a participant's assessment (i.e., a distance of 2 would be if a sender rated a message *neutral*/0 and a receiver rated it *very sad*/-2). Then, a paired sample t-test by participant was performed on the overall mismatch distance between ratings in messages with and without indicators, given that H_0 = tone indicators did not affect the mismatch distance of participants' affectual assessments, and H_a = tone indicators lowered the mismatch distance of participants' affectual assessments. To

examine the measure of affectual expressiveness, a paired sample t-test by participants was performed on the absolute value of sender ratings in sessions with and without indicators, given that H_0 = tone indicators did not impact the absolute value of sender ratings and H_a = tone indicators increased the absolute value of sender ratings. Then, effect sizes and confidence intervals of any effects of tone indicators on either affectual accuracy or expressiveness were calculated, respectively.

3.4.2 Conversational Quality Analysis. Participant experience of the six conversation qualities of *Affect, Depth, Equality, Formality, Immediacy,* and *Trust* were documented through post-session questionnaires formatted in a 5-point Likert scale [15] (see Appendix A). To evaluate this data, the questionnaire responses were divided by respective subsection/quality and experimental condition, numbered according to the 5-point scale, and averaged. A Wilcoxon signed-rank test was then performed on participant ratings across each of the 6 qualities, paired by sessions with and without tone indicators, given that H_0 = tone indicators did not impact ratings of (quality) and H_a = tone indicators increased ratings of (quality) [46]. This was done as the rating data was non-normal and ordinal. In addition, to mitigate the impact of multiple comparisons, we report the results of the tests with the Benjamini-Hochberg procedure applied [4].

3.4.3 Qualitative Analysis. To gain insight into participants' prior experiences with both tone in CMC and the tone indicator tool, a thematic analysis of interview transcripts was conducted. Drawing from Braun and Clarke (2006, 2019), the first two authors used an inductive approach to derive codes independently [7, 8]. Afterward, the authors met to compare codes and collaboratively refine the codebook on areas of consensus, dissensus, and overlap—ultimately settling on 12 codes. Utilizing this refined codebook, each interview was manually coded and subsequently synthesized into overarching themes. There was strong agreement between the two coders, with an inter-rater reliability (IRR) of 0.87 using Cohen's Kappa. Broad themes included: *the impact of neurodivergence on CMC, prior experience with tone indicators, the process of using the tone indicator tool, the impact of tone indicators on conversational experiences, thoughts/comments on the potential of neurodiverse accessibility features.* More nuanced and directional codes under each overarching theme were further applied to capture more specific aspects of participants' experiences, such as *increased control over expression* and *found translating feelings into indicators difficult.*

3.5 Ethics & Positionality

This study was designed with the explicit intent of researching ways to improve accessibility. To do so, we consulted the work of disability justice advocates and researchers to gain knowledge of the common areas of harm in designing accessibility aids and around neurodivergence generally. The study procedure was piloted with neurodivergent volunteers who gave feedback on its design. This study was also approved by the researcher's IRB to ensure that principles of informed consent and ethics were upheld.

4 RESULTS

In this section, we synthesize qualitative and quantitative findings to analyze the impact of tone indicators on individual participants' experiences of tone interpretation, expression, and cognitive load, as well as on conversational pairs' experiences of conversational quality and flow. We also discuss observations of messaging behavior in relation to other CMC cues, along with participants' overall insights into the utility of tone indicators in more naturalistic settings.

4.1 Impacts on User Self-Presentation, Affective Expressiveness, and Cognitive Load

4.1.1 Tone indicators increased overall participant expressiveness and provided greater control over self-presentation: Analysis of the Visual Scale Assessment found that tone indicators significantly impacted the average affective expressiveness of participants ($t = 7.078$, $df(988)$, $p <= 0.05$, $\Delta M = 0.22$), increasing the overall affective expressiveness of neurodivergent users. While the quantitative effect size of this change was small ($d = 0.35$), post-study interviews indicated that tone indicators provided participants with greater control over their self-presentation in their communication and reduced the burden of social masking. Participants detailed how they would use indicators to disambiguate their message, highlighting how *"that's crazy,' could be sarcastic or not"* and *"if someone tells you that a show is really weird, I'm like nice!"*

Participants expressed that they used the `/gen or /g` indicator to *"make sure that the person knew that [my message] was genuine"* because they "*don't always know how other people will perceive their tone"* (P13, P7). In particular, participants noted that tone indicators provided a more direct avenue of self-expression and clarity than other paratextual cues like emojis or text styling, explaining:

> *"Without my own tone indicators, the only things I'm familiar with are using emojis or using an exclamation mark to show that I'm in a good mood. That's pretty limited, so for my own communication, these indicators gave me a stronger sense of control and assurance compared to using [emojis]. How else can I convey I'm genuine? There's no emoji for that."* (P4)

Other participants detailed that these indicators also provided them with a means to retain their natural messaging style. One participant recounted that the usual way they texted was *"without a whole bunch of exclamation points or anything, which all of the people interpret as 'oh you're not really interested"',* but that tone indicators *"aided in my way of still being able to maintain my normal communication while having someone who I'm not familiar with be able to understand"* (P2). For participants for whom common paratextual tone cues like emojis, "lols" and capitalization require high mental energy to interpret or just feel unnatural to use, tone indicators provided a means of self-presentation with comparatively greater accuracy and lower cognitive load. As one participant put it:

> "*On long days, I have to tell people I'm not actually mad; I just don't have the energy to translate it into exclamation code language."* (P2)

4.1.2 Tone indicators did not affect the base accuracy of user tone assessments, but did increase user confidence in interpreting tone. Through Visual Scale Assessments, we found that there was no significant effect of tone indicators on affectual mismatch of participants ($t = -0.097$, $df(1105)$, $p = 0.92$, $\Delta M = 0.002$), suggesting that indicators did not improve the accuracy of neurodivergent individuals in perceiving affect.

However, thematic analysis of participant interviews revealed that while tone indicators did not increase an individual's accuracy in interpreting tone, they did increase their confidence in doing so, lowering overall conversational anxiety. Participants frequently recounted instances during the study where the inclusion of tone indicators provided assurance, saying *"I would have been able to figure it out, but it felt like having the tone indicators gave my interpretation more confidence,"* and

> [referring to a message]: *"That's kind of an aggressive message to send without the /joking. I probably could have gotten that that was a joke, but [the indicator] definitely helps."* (P8, P10, P17)

While some participants ultimately were able to figure out the tone of a message, the inclusion of tone indicators from their conversation partner provided a level of assurance that one participant put simply, "*helped me understand what they're going for and alleviated some anxiety"* (P1).

Category	ΔM	Z	P-value	Cohen's d	P-value (BH Adjustment)
Affect	***0.250***	***4.33***	***0.00725****	***0.721***	***0.0217****
Depth	***0.410***	***3.60***	***0.00237****	***0.600***	***0.0142****
Equality	0.105	4.23	0.606	0.704	0.606
Formality	0.0630	2.60	0.3059	.433	0.367
Immediacy	0.138	3.13	0.1485	0.521	0.223
Trust	0.105	3.34	0.1293	0.556	0.223

Fig. 3. A table with the results of a Wilcoxon signed-rank test for Affect, Depth, Equality, Formality, Immediacy, and Trust, where H_0 = tone indicators have no impact on (quality), H_a = tone indicators have a positive impact on (quality). Mean difference in average rating, W-value, effect size, and p-values with the Benjamini-Hochberg procedure applied are also included. Affect and Depth categories are further bolded to indicate that significant effects were found.

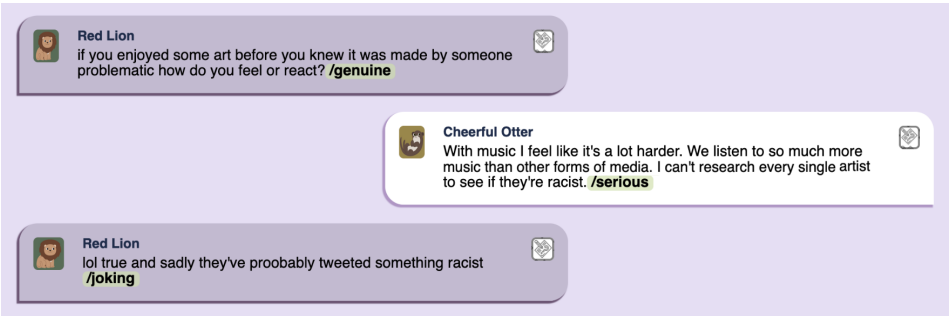


Fig. 4. An example exchange from a discussion referred to by P1 during which indicators contributed to the clear transition between conversation tone.

> *"Actually seeing the indicator helped with my anxiety. To know, I'm not being annoying, or they're actually interested in what they're talking about....kind of just destroying all the possible negative thoughts I would have."* (P2)

Overall, while the participant interviews suggest that individuals were ultimately able to effectively perceive the tone of others while messaging, they indicated that tone indicators were valuable as a means of increasing the clarity of the perceived tone and, in doing so, reduced conversational anxiety.

4.2 Impacts on Dyadic Conversational Quality, Behavior, and Social Connection

4.2.1 The indicators positively influenced conversational quality within a pair, increasing overall discussion affect and depth: The post-session survey measured participants' high-level experiences with six dimensions of conversational quality (*Affect, Depth, Equality, Formality, Immediacy,* and *Trust*) on a 5-point Likert scale. Paired-sample t-tests were performed on each conversational quality subset, comparing sessions with and without tone indicators by participant mean rating. As noted in Figure 3, we found that tone indicators had significant positive effect on the mean participant ratings of *Affect* ($Z = 4.33$, $p <= 0.05$) and *Depth* ($Z = 3.60$, $p <= 0.05$), but no significant effect on the qualities of *Equality, Formality, Immediacy,* and *Trust.* The effect size with *tone indicator* condition had a large effect size for both *Affect* ($d = 0.72$) and *Depth* ($d = 0.60$). These results are in line with the qualitative finding that participants were more expressive in messages that used tone indicators, a quality that is closely linked to high-level experiences of conversation quality [26].

4.2.2 Increased conversational fluidity and social connection: In line with the quantitative findings on increased expressiveness and improved experience with affect and depth, participant interviews suggested that tone indicators improved overall perceived conversational fluidity and affect. Participants explained that indicators' presence made tonal transitions more clear, referencing exchanges captured in Figure 4, noting *"we kind of switched from more of a joking type thing to talking more serious"* and *"it helped with that [shift]"* (P1). Another participant indicated that by explicitly tagging these transitions, the conversation was more *"engaging"*, recounting:

> *"The [two] conversations where we used the indicators, the conversation was more…fluid, and we moved away from the original topic into something that we were both interested in talking about."* (P8).

Furthermore, participants noted that sessions without tone indicators "*felt like things came across much more flat on both their end,"* explaining:

> *"Without tagging the tone, it was just a little bit harder to tell what the other person was* ***feeling*** *unless there were like a bunch of exclamation marks or something; and that too requires the mental load of de-coding."* (P12).

In increasing the confidence of participants in both perceiving and communicating tone, tone indicators also contribute to a generalized increase in communicative fluidity and expressions.

4.3 Impacts on User Messaging Behavior and Alternative CMC Cue Use

4.3.1 Participants used tone indicators in conjunction with, rather than in substitution for other CMC cues: Analysis of backend messaging behavior (individual keystroke character, timestamp, etc.) indicated that using tone indicators was positively correlated with participants' use of other CMC cues. For messages that were sent with tone indicators, around 31% also included at least one other cue. In comparison, of messages that were sent without tone indicators, 24% included non-TI cues. A chi-squared test was performed to examine if the presence of tone indicators and cues was independent. We found that tone indicators were significantly positively associated with the presence of other CMC cues ($x^2 = 11.70$, $df = 1$, $p <= 0.001$). This positive association indicates that the indicators did not significantly modify users' utilization of other CMC cues and that participants integrated them as an add-on to other cues.

4.3.2 Messaging behavior varied in typing speed and message length: Participants consistently typed slower in sessions where indicators were used with an overall mean difference in milliseconds of $\Delta M = 61.23$ and a standard deviation of $SD = 45.7$. The individual impact of tone indicators on the individual keystroke speed of participants ranged from a minimum of -27ms to a maximum of +142ms. The typing speed was calculated without including the time it took participants to select the appropriate tone indicator (since that would be a confounding factor).

Message length was variously impacted by the introduction of tone indicators ($\Delta M = 9.91$, $SD = 34.82$), with individual mean differences in character length in sessions with and without tone indicators ranging from +67ms to -61ms. As highlighted by Figure 5, when using the indicators, the average message length of most participants' messages increased by more than 75%, and decreased two participants' average message lengths by around 50%.

From a user perspective, the later quantitative analysis of participants' post-discussion ratings shows that participants' experiences of immediacy remained unaffected by the introduction of these indicators, implying that the lower average keystroke speed of the sessions with tone indicators may not directly correlate with participants' overall engagement or experience of engagement. It is thus ambiguous from this descriptive analysis whether such observation on users' messaging speed

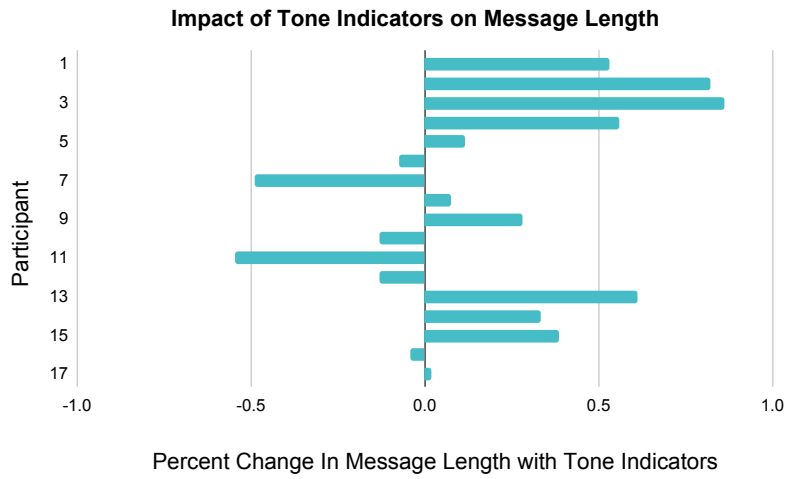


Fig. 5. Percent change in message length in sessions with tone indicators by participant, showing most participants typed overall longer messages.

and length can be attributed to a higher-level effect on conversational patterns or to the potential learning curve that comes when introducing novelty in existing applications.

4.4 Social Dynamics and User Preferences for Tone Indicators

4.4.1 The utility of tone indicators and other respective CMC cues varied based on participants' social landscapes and the respective alignment of communication norms: Participant interviews highlighted that tone indicators were widely familiar to the participant pool, with over half of participants actively using them with peers and only three who had never encountered them before. Within the subset that had actively used them with peers, participants highlighted that their use of tone indicators depended on social circumstances, noting:

> *"There are specific friends that need them, but even when communicating with people who are familiar with my communication style, I use them to help me so my message comes across exactly the way I intend to."* (P12)

Participants noted that in their daily lives, tone indicators were less helpful in the one-on-one setting of the experiment, saying:

> *"They're really most helpful to me in situations where I'm either talking in a group of people that's not all neurodivergent or of the same gender."* (P12)

Others indicated that tone indicators would especially be helpful in settings with more prescribed social expectations, such as in professional emails or with older adults, explaining that *"I think using tone indicators over email could be like a game changer. I would love that so much"* and

> *"I would like them in situations where the other person interacting might just have very different texting styles [...] I feel this with my parents because they don't understand what lol means."* (P9)

In line with these accounts, it was notable that the participants who indicated that tone indicators were less impactful on their session experiences were those who had expressed establishing explicitly negotiated paralinguistic cues within close social circles, providing examples like *"me and my friend*

made a fake emoji where like you can send an empty message on Apple messages, and we just agreed that empty message means 'real'" and *"in a conversation with some of my best friends I feel free to express myself through adapting the text because I feel like those are things that they expect of me and I expect of them"* (P13, P5).

4.4.2 Participants expressed diverging perspectives on the trade-off between the variety and clarity of tone indicators: In evaluating the tone indicator tool itself, participants expressed diverging experiences with the more limited list of tags, indicating a more general tradeoff between clarity and flexibility of expression (the tags were:

```
\genuine, \positive, \negative, \sarcastic,
\not mad, \a little upset, \joking,
\serious, \not serious, \metaphorically,
\hyperbole, and \teasing.
```

another participant noted that:

> "*It was nice that they were prescribed, and I knew that the other person had the same rules. It felt like we were choosing from the same book, like speaking the same language.*" (P8)

Others found the limited set challenging, stating "*I like the idea of tone tags, but having to choose between a set of them stressed me out a little bit because I feel like I have to internally assess and categorize my tone. The feeling that I'm conveying or like the feeling that I want to attempt to convey and whatever all tends to be pretty specific*" (P3). One tone indicator that particularly reflected this potential tradeoff between clarity and flexibility was *half – joking*, which was not part of the experimental set. While one participant called out that the selection "*was missing half – joking,*" another explained:

> '*I've seen /half-joking, which I don't really understand. I think that one doesn't make any sense because, like, why would you be half joking? If either you're joking or not, if you like.*" (P1, P14).

5 DISCUSSION

In this section, we discuss how tone indicators can support neurodiverse communication, their role in establishing CMC norms, and their potential impact in neurotypical-dominated spaces. We highlight the trade-offs for customizing CMC cues and how such considerations may align with ongoing CMC work in co-customization. Lastly, we discuss the broader implications of our study when designing for disability-informed social interaction design.

5.1 Supporting Neurodiverse Communication Through Structured and Explicit Cues

Our study introduced a supplementary feature of CMC cues specifically designed to support neurodivergent communication needs, prioritizing the scaffolding of structured and explicit social cues highlighted in prior work [30, 44, 48]. Previous research has highlighted how the existing design of messaging applications places a burden upon users to *"translate exclamation code language"* [6, 24, 44, 47]. In response to this challenge, we found that tone indicators a) reduced the cognitive load needed to interpret tone and b) made online communication feel more intuitive and connected for neurodivergent users. Participants reported higher confidence and immediacy when interpreting the tone of a message, which in turn afforded greater control over self-presentation and conversation flow.

By reducing the anxiety of being misunderstood, tone indicators allowed participants to maintain their normal communication style. In conjunction, participants rated both their own messages and their partner's messages as more expressive, even when using other CMC cues. This positive impact extended to overall conversation quality, greater emotional engagement and deeper discussions.

Participants also found tone indicators useful for signaling *shifts* in conversation flow, providing a more structured way to navigate and pace discussions. Notably, our analysis of participants' messaging behavior showed that tone indicators did not replace other CMC cues, such as emojis or text stylization. In other words, tone indicators were used as a *supplement*, not a substitution for current CMC cues, suggesting that there is no reduction in the overall informativity of neurodivergent user messages, only an alteration of the clarity and delivery of such information.

In light of ongoing research to improve emotional cues [1, 21, 22] and communication richness in CMC [26], our study highlights how simple design features like tone indicators can provide the needed structure for neurodivergent users without necessarily compromising existing design strategies in CMC. Even when tone indicators are used asymmetrically, where one user prefers them and another relies on a different paralinguistic cue, both participants benefit, as the former is afforded more intuitive ways to self-present, while the latter experiences greater conversational expressiveness. These findings position **tone indicators as a grounded exploration of disability-informed design principles** in social technology [5, 30, 44, 48].

5.2 Going Beyond a One-Context-Fits-All Understanding of CMC Cues

Prior research on social technology and disability [33] highlights how "individuals with disabilities must perform additional labor to navigate complex norms in social interaction". Similarly, the manual burden of customizing for the needs of a neurodivergent user once again falls on the said user. Participants described "inventing" their own communication strategies to convey tone, ranging from empty messages to predefined collaborative strategies, such as agreeing that 💀 meant *"laughing so hard that I'm dead /joking."*

At the same time, our analysis also highlighted the varied opinions and the context-dependent use of tone indicators, reinforcing that designing for accessibility and richer text-based interaction cannot follow a one-size-fits-all approach (where size refers to context) [26]. Participants noted that they naturally adopt text stylizations and emojis through common use and agreement with friends, and thus, the explicit nature of tone indicators was less of a benefit to them. The impact of tone indicators seemed to be proportional to the ambiguity of social cues, of which the ambiguity is shaped by both exposure and explicit negotiation amongst members of a social network.

Beyond context-dependent use, there exists another challenge: the standardization of tone indicators. For instance, beyond widely known indicators, some participants found certain indicators, like `/half-joking`, to be vague. These findings aligned with prior research on the challenges of paralinguistic cues [26, 47–49], as what seems intuitive to a user may not be for their conversational partner. While no such issues emerged with with the specific tone indicators used in our study, there appears to be a point at which individual tone indicators could become too abstract to remain helpful.

5.3 Reconciling Contextual Trade-offs in Tone Indicators Through Co-Customization

Participants discussed the trade-offs between variety and clarity in tone indicators, depending on the demands of different social contexts. They found these indicators helpful in unfamiliar social contexts but sometimes restrictive in familiar settings. The perceived value of these trade-offs also varied according to a user's individual relational and communication needs [26].

Existing work on CMC, especially collaborative approaches to cue customization, [21–23], may, in turn, present a means through which neurodivergent users can personalize their use of the indicators. Some participants were already engaging in co-customization, as one explained: "*My friend and I made a fake emoji where you can send an empty message, and we agreed that it means 'for real'*" (P13). Since the accessibility of social cues depends in part on social contracts in online environments,

co-customization offers mechanisms for neurodivergent users to negotiate both the **clarity** and the **diversity** of CMC cues.

However, such co-customization needs to be reconciled with the fundamental nature of tone indicators: explicitly tagging tone or intent. As supported by current participatory work, such reconciliations can be achieved by incorporating additional structures within the customization process [48]. Specifically, providing users with specific processes, stages, and scaffolding to guide the customization and adaptation of cues [26]. In other words, if a neurodivergent user finds the indicator `/half-joking` to be ambiguous, future implementations should include built-in mechanisms for collaborative disambiguation. As our findings suggest, collaborative cue customization can provide the desired clarity and intersubjectivity for neurodivergent users. Current advancements in CMC may likewise be able to leverage such co-customization methods and explicit user negotiation as a means to improve communicative accessibility.

5.4 Considering Tone Indicators in Mixed-Type Interactions

In this study, we focused on neurdiverse users' communication to ground the analysis of tone indicators in neurodivergent communication styles. Prior work has outlined that communication within a neurodivergent community does not inherently mean that individuals' relationship to expressing tone and intent is the same or that the challenges of such are neutralized. The reason neurodivergent spaces are different from neurotypical spaces is not because the former are different from the latter but because neurodivergent users are also very different from each other [40]. As such, in this study, which seeks to center our analysis on the social experiences of neurodivergent users, we chose not to introduce a mixed-neurotype setting. However, our analysis has broader implications both in the sense of scaffolding neurodivergent communication and in understanding the contextual use of tone indicators beyond.

In particular, we highlight tensions in the social dynamics and user preferences for tone indicators (Section 4.4) that lay the groundwork for sociotechnical design research in more diverse social settings. In contrast to the widely accepted Theory of Mind framework, which often frames communication breakdowns as stemming from the 'social deficits' of neurodivergent individuals rather than an equal mismatch of neurotypical communication dynamics [2], we highlight the Milton [29] 'Double Empathy Problem', which proposes that mixed-neurotype interactions should be understood as a matter of reciprocal interaction. Our work, in alignment with Milton [29], calls for future work to investigate how tone indicators shape CMC norms within cross-neurotype communication and whether they have the same benefits or if they, too, become subject to interpretive challenges and miscommunication, as is often the case with other paralinguistic cues [6].

5.5 Establising CMC Norms through Disability-Informed Collaborative Practices

There are multiple trade-offs to consider when considering how tone indicators can be helpful in establishing new communication norms. While in some cases, normalizing tone indicators might mitigate the cognitive load for neurodivergent individuals in activities like online conflict resolution, on the other hand, such strategies could induce social stigma if neurotypical participants are not as receptive or reciprocal. This could lead to increased misinterpretation, particularly if neurotypical individuals are not accustomed to interpreting these indicators or perceive them as unnecessary. This raises a question about how such norms might emerge organically and whether they would be universally accepted across neurotype boundaries. In other words, given that neurodivergent individuals are already vulnerable to stigma in online settings [9, 33], would the establishment of new CMC norms of public use of alternative cues further cause ostracization? In addressing such questions in future work, we want to emphasize a) the critical inclusion of neurodivergent stakeholders throughout the design and research process, and b) call upon future work to investigate

these complexities and clarify the benefits and challenges of integrating tone indicators into a variety of communication environments, from neurodivergent communities to neurotypical-dominated spaces.

As highlighted first in the introduction of this study, there is not only a notable lack of social computing research for neurodivergent adults but also of research that properly incorporates disability-informed perspectives—an absence that manifests in poor and dehumanizing practices like that of dismissing self-reporting methods because of perceived 'mental incompetence' or creating technology that intends to normalize 'divergent social behavior' at the expense of neurodivergent users themselves [12, 30]. However, like all designs, designing for neurodiverse accessibility cannot happen absent of user perspectives [37, 38]. Thus, we call for future work to address the social factors around communicative aids and the establishment of new CMC norms and to do so with express consideration for and further construction of disability-informed collaborative CMC practices.

5.6 Limitations and Future Work

While this study has worked to propose and identify the benefits of alternative cue features like tone indicators, future research needs to be done in order to better contextualize neurodiverse accessibility in CMC, especially on group dynamics. In particular, this experiment was conducted with a population of participants that were predominantly university students, a demographic that represents only a subset of neurodivergent users and their relative communication needs. However, tools like tone indicators may impact the experiences of members in social groups or environments with a diverse spectrum of users, including those who are neurodivergent with varying support needs, as well as neurotypical individuals who have difficulty conveying tone. Expanding the integration of such accessible tech beyond the study's peer-to-peer discussions may lead to the emergence of both unique challenges and benefits.

In addition, while our study design allowed us to explore tone indicators specifically within neurodivergent communication, our work does not capture how these indicators function in mixed neurotype interactions, where miscommunications often arise [29] which often overlooks the role of neurotypical misinterpretations and the broader issue of disability cultures being unrecognized in primarily neurotypical spaces [2, 29]. We call upon future work to examine how tone indicators impact different social interaction styles, and incorporate qualitative evaluations from mixed-type interactions for establishing more inclusive CMC norms in neurotypical-dominated spaces.

6 CONCLUSION

In this study, we contribute to the design and validation of tone indicators as a communicative accessibility feature, providing an empirical understanding of how such supplementary cue systems can be utilized to further inclusive CMC technology. In examining the contextual use and utility of tone indicators, our analysis shows that tone indicators were able to facilitate greater access to and production of social information by providing directly informative cues, thus enabling users to have more control over self-presentation and confidence in tone interpretation. In turn, this increase in the clarity of social signaling resulted in a more fluid and expressive conversation between participants, which boosted dyadic experiences of effect and depth. Further, our study highlighted how participants' struggles with cue ambiguity both prior to and within the experimental sessions were informed by social context and collaboration. In interpreting these results, this work not only discusses ways in which tone indicators can be further implemented to support neurodivergent communication styles but also provides guidance for how ongoing CMC research can inform and incorporate considerations of neurodiverse accessibility.

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A CONVERSATION QUALITY QUESTIONNAIRE

Immediacy

- My partner was intensely involved in conversation.
- My partner found the conversation stimulating.
- My partner showed enthusiasm while talking to me.
- My partner acted bored. (R)

Affect

- My partner communicated coldness rather than warmth. (R)
- My partner was interested in talking to me.
- My partner did not want a deeper relationship between us. (R)
- My partner was NOT attracted to me. ® stike
- My partner created a sense of distance between us. (R)

Similarity/Depth

- My partner acted like we were good friends.
- My partner seemed to desire further communication.
- My partner acted very friendly.
- My partner tried to move the conversation to a deeper level.
- My partner made me feel they were very similar to me.

Receptivity/Trust

- My partner was very honest in communicating with me.
- My partner was willing to listen to me.
- My partner was sincere.
- My partner was open to my ideas.

Formality

- My partner made the interaction very formal.
- My partner wanted the discussion to be casual. (R)

Equality

- My partner considered us equals.
- My partner did NOT treat me as an equal. (R)
- Involvement
- How involved or uninvolved was your partner? How attentive or distracted was your partner?
- How interested or indifferent was your partner?

B DISCUSSION PROMPTS

(1) What's the most unconventional hobby or interest you have, and why do you enjoy it?
(2) Do you believe that people's personalities are shaped more by nature or nurture? Why? How do you see this play out in your own life?
(3) Share your opinion on whether technology brings people closer together or drives them apart. Why do you think this way?
(4) Find a shared piece of media you've consumed and discuss it. Do you have similar opinions on it? Any disagreements?
(5) Do you think you can separate the art from the artist? How do you view the balance between artistic freedom and social responsibility?
(6) Explore the impact of technology on modern relationships. Are social media or dating apps helping or hindering the search for meaningful romantic and platonic connections?

(7) Do you follow social media influencers or celebrities closely, and if so, why? If not, what influences your decision? What are your thoughts on the role of influencers and celebrities in today's digital landscape?

Received October 2024; revised April 2025; accepted August 2025