The Depressed Teenage Brain: Chatbot Psychoeducation

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Abstract

Objective: To gain the knowledge needed to develop a cognitive behavioral intervention and reliable psychoeducation applicable for conversational artificial intelligence models, we investigated the underlying constructs of thoughts common to cognitive distortions found in online questions written by adolescents with symptoms of depression.

Methods: From June 30, 2020, to October 30, 2020, we analyzed a sample of 100 written questions from adolescents about depression posted on an online information service using a qualitative analysis guided by cognitive behavioral theory and informed by the neuroscience of adolescence.

Results: Four types of cognitive distortions (CDs) were found: (1) emotional reasoning, (2) mind reading, (3) catastrophizing, and (4) labeling. Our analysis suggested 3 underlying constructs common to the different CDs: (1) emotional states appearing as reality, (2) experiencing this emotional reality as something others think, and (3) generalizing such beliefs to every relation and the future. These constructs may signify events leading to a ruminative state that seems hard to escape.

Conclusion: The 4 different CDs originate from 3 underlying constructs possibly associated with adolescent neurodevelopment. This study indicates a potential to reveal the underlying constructs of thought common to different CDs, thus making CDs more useful as a target point in artificial intelligence—based technological information and intervention tools.

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Subthreshold depression and major depressive disorder[1-3] are common during adolescence, and teenagers often avoid seeking help.[4] Adolescent depression is associated with later mood disorders, other mental health problems, and severe mental illness.[5,6] Adolescence is a critical developmental period that could significantly affect both mental and physical health. The potential of long-term effects on prefrontal functions[7,8] makes it imperative to prioritize early, low-threshold therapy for this age group.[9]

New technologies based on artificial intelligence (AI), such as low-threshold conversational AI, are seen as a promising approach to improve adolescent health services. There is a need for research on how such conversational AI can contribute to clinical practice,[10] deliver psychoeducation, and offer initial therapeutic reattribution.[11-14]

This study addresses one potential strategy to strengthen such conversational AI: to create models capable of detecting cognitive distortions (CDs) or distorted thought patterns present in written conversations of adolescents with depression symptoms. These models may identify the units of meaning and serve as an initial step in developing trustworthy and relevant psychoeducation using conversational AI. Within the realms of cognitive behavioral therapy (CBT),[15,16] CDs have received increasing attention as a therapeutic target and may play an important role in depression sustainment and negative cognitive spirals.[17] In the literature, important CDs are all-or-nothing thinking and labeling, alongside

those typically found in the adolescent population: catastrophizing, overgeneralizing, personalizing, selective abstraction, mind reading, emotional reasoning, and underestimating the ability to cope.[17] Cognitive distortions are acknowledged as erroneous patterns of negative automatic thoughts preceding an emotional, behavioral, and/or symptom response.[15,16] Activated by situational stressors, negative automatic thoughts and the different CDs are hard to distinguish and appear unified in meaning by possible underlying constructs of thoughts.[18]

However, to train AI models to identify and ultimately respond to CDs, we need more knowledge about these underlying constructs to develop an accurate conceptual framework. This knowledge gap could be filled by investigating the content of meaning shared by different CDs, that is, underlying constructs of thoughts, possibly explained by biological principles of modern neuroscience.[19]

New knowledge about the neural mechanisms involved in depression could support the theories of CBT in adults.[20] Adolescence may represent a stage of brain development at which cortical and limbic functions amplify the affective response of negative cognitive spirals and aggravate symptoms of depression.[21]

First, neural processes are involved in perpetuating maladaptive beliefs. A depressed mood could affect memory encoding and recall, forming biased beliefs. Biased memory encoding and recall could affect mood, causing negative cognitive spirals.[22,23] Second, depression is linked to overactive bottom-up pathways from the amygdala and thalamus to the prefrontal cortex (PFC).[22] This pathway is more excitable in adolescence.[21,24] Adolescents experience stronger emotions due to higher ventromedial PFC influence and amygdala activation,[25] leading to a weaker ability to disengage from negative stimuli.[22] Depressed adolescents appear biased toward negative stimulus perception. Third, adolescents struggle to distinguish between imagining what peers think about them and what they think about themselves.[24] Adults make such distinctions through an intricate interplay between PFC and limbic functions, whereas adolescents tend to experience the 2 phenomena as similar.[26,27] Finally, adolescents lack emotional self-regulation owing to incomplete development of anterior cingulate cortex (ACC) connections in the central nervous system. Immaturity of ACC and reduced dorsolateral PFC control may intensify the emotional impact of stressors.[8,21,22]

On the basis of the aforementioned knowledge gap identified, we aimed to respond to the following research questions:

1. Research question 1: Which CDs are found in an online self-reporting dataset of posts revealing symptoms of depression?
2. Research question 2: Are there similarities between the different CDs suggesting underlying constructs of thoughts?

This study aimed to investigate the quality of depressogenic CDs in adolescents and identify potential underlying thought patterns. This was achieved by analyzing written questions about depression that were posted on an online information service for adolescents, ung.no. By aligning the analysis with cognitive theory and the neural mechanisms of the adolescent brain, this study aimed to enhance our understanding of the shared thought patterns that contribute to different CDs.

METHODS

Data and Participants
Ung.no is an online information and question-and-answer service for adolescents provided by the Norwegian Directorate for family, adolescent, and child affairs. At ung.no, relevant personnel (eg, psychologists, doctors, and nurses) respond to written questions (posts) about a variety of topics. Adolescents (users) can choose the relevant topic from a pull-down menu, one of which is mental health and emotions. On posting a question, they specify their sex (male, female, or other) and age (13-20 years). By recognizing descriptions of depressive symptoms or by interpreting the entire post as displaying a depressed mood, the personnel label the posts according to distinct categories and category levels. One of these is depression. Available data consisted of a total of 277,552 posts in Microsoft Excel (MSE) format, of which 14,804 posts belonged to the mental health and emotions categories. Among these, 870 posts were tagged with depression as category level 1, from which
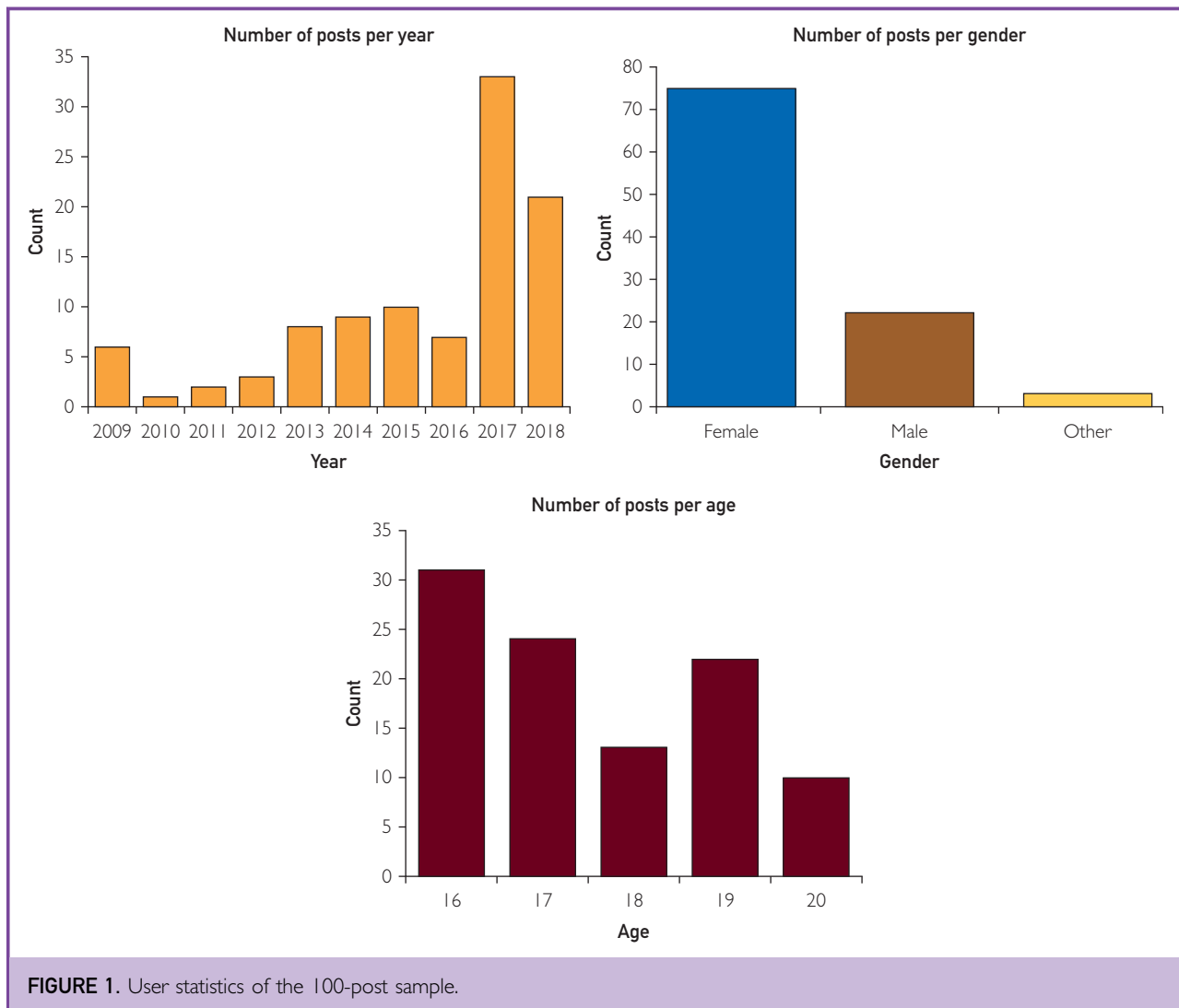
FIGURE 1. User statistics of the 100-post sample.

we randomly sampled 100 posts for analysis. Figure 1 provides further details about the properties of the 100-post sample. Each post was given a unique identification (ID) number. Quotes from the posts were paraphrased to disallow readers from tracking the quotes back to the original posts.

The users frequently described events leading to the symptoms of depression: narratives exhibiting activating factors, the ensuing CDs, and the emotional, behavioral, and symptom response. Self-reported free-text data from online sources are spontaneous in nature and are assumed to be a useful source for assessing depressive symptoms and even severity.[28] Self-perceived mental states are known to match the clinical diagnoses given by professionals.[29]

Procedures

From June 30, 2020, to October 30, 2020, we analyzed the 100-post sample following the stepwise procedure of Giorgi's[30] phenomenological analysis. As the first step, 2 raters (K.K.D. [a general practitioner] and J.I.R. [a psychiatrist]) educated and trained in CBT familiarized themselves with the data, grasping the basic sense of the material: the narrative structure, the appearance of different CDs, and the similarities in the underlying constructs of thoughts between the different CDs. We found CDs appearing in 48 of the

posts in the sample. We found only 1 CD in each post. After analyzing 25 posts, no new CDs were found.

In the second step, both raters defined the phenomenological object: the activating events as they appear in the life of the user and how the users respond to stressors triggered by distorted automatic thoughts—the CDs.

In the third step, the first rater (K.K.D.) identified and coded the units of meaning using the NVivo Pro 12 application for qualitative analysis: naming the different CDs stated in the posts. This step differs from Giorgi's procedure that implies the use of slashes to mark transitions of meaning throughout the entire text. Contrarily, we coded only the units of meaning that were deemed relevant to the research questions. The second rater (J.I.R.) read the posts and approved or disapproved on the units of meaning and coding. After 10, 40, 80, and 100 posts, the coders met to reflect and agree on the coding. Reflections concerned whether or not the raters' preconceptions could affect the analysis and to what extent the codes represented the similarities of the same classes.

As the fourth step, using MSE for the rest of the analysis, the first rater (K.K.D.) rephrased all the analyzed posts into third-person abstractions. Anchoring the analysis in cognitive theory means that these abstractions display an interpretation of the meaning of the CD in the context of the entire post, concurrently creating the categories resembling the common meanings of the different CDs, that is, the underlying constructs of thoughts. Informing the analysis by neurobiological models means comparing these underlying constructs with affective and cognitive neural mechanisms.

In MSE, the different underlying constructs of thought were given individual colors. Using the MSE cell color fill function, a visual pattern displaying the distribution of different underlying constructs across the CDs was depicted (Figure 2). Each CD contained different underlying constructs, with the underlying constructs being common to the different CDs.

Finally, the categories were discussed in an analysis meeting with the entire team of researchers, comparing the categories with the original data, considering the theoretic anchoring.

RESULTS

Study Characteristics

The initial process of coding revealed the following 4 different CDs:

1. Labeling: the person generalizes negative characteristics about oneself or another, applying it to the whole person.
2. Mind reading: believes knowing what others think.
3. Emotional reasoning: what the person feels is experienced as true.
4. Catastrophizing: the person believes that everything will go wrong on the basis of a belief about presumptions becoming facts.
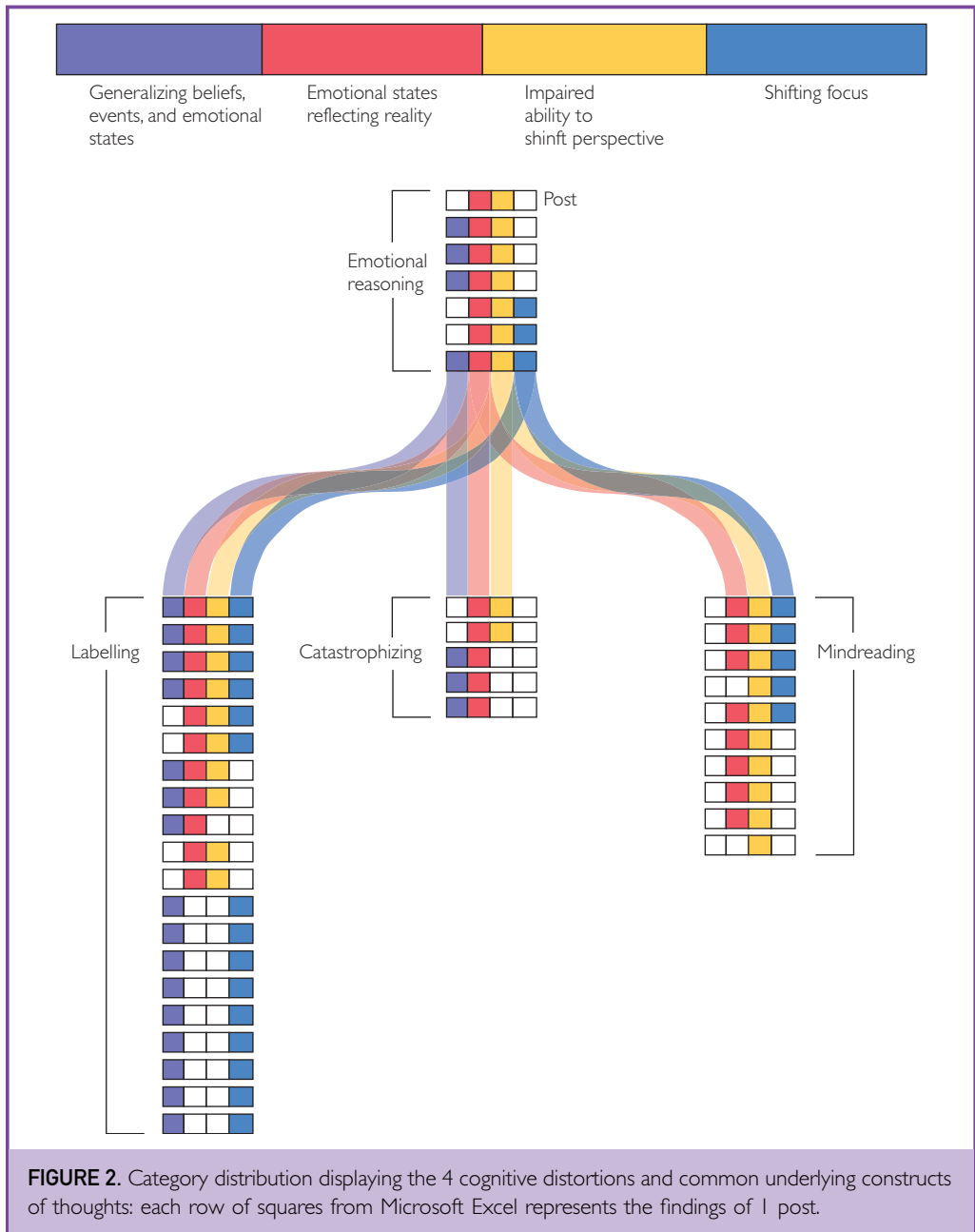
The ensuing process of categorization revealed contents of meaning expressed in the posts when the users conveyed the text narratives: exposed to stressors and certain ways of thinking appearing common to the different CDs. As displayed in Figure 2, these underlying constructs of thoughts were organized into 4 categories.

Category 1. Generalizing Beliefs, Events, and Emotional States This category represented the generalization of specific self-perception traits of past events and affective states. It was divided into 3 subcategories:

1. Global beliefs about oneself, applicable to every life situation.
2. Generalized causality—generalizing every past single or multiple events to every future event.
3. Emotional states becoming rules, applicable to every situation.

This category and its 3 subcategories seemed to be characterized by the construct of generalization that is common to the CDs of emotional reasoning, labeling, and mind reading. Global beliefs about oneself seemed to dominate the CD of labeling. Such globalized beliefs were also present in the CD of catastrophizing. One user stated the following: "I'm stupid and everything is bad, and this is how it will always be" (ID: 218261).

In the subcategory of generalized causality, single or multiple past events represented the rules for future events after the same causality, exemplifying a construct based on experience and drawing the same conclusion for future

FIGURE 2. Category distribution displaying the 4 cognitive distortions and common underlying constructs of thoughts: each row of squares from Microsoft Excel represents the findings of 1 post.

events. "I have thought about seeking help, but nothing will ever make me better" (ID: 156008).

Emotional states becoming rules dominated the CDs of labeling and emotional reasoning. Such beliefs may be associated with affective states contributing to the process of generalization. We discovered the primary emotions of shame, disgust, sadness, and

fear. The following post extract exemplifies the link between the underlying generalized belief and the emotions of self-disgust: "No wonder I almost have no friends, I can't keep them, and I can't make new ones because I am such a dumb introvert." (ID: 149740).

Category 2. Emotional States Reflecting Reality In category 2, different emotional states

were perceived as true, displayed by the imagined consequences: "I'm so afraid of making mistakes. It's not visible from the outside, but inside all is broken. I'm so confused and may start crying for nothing. People think I am strong. But I'm not." (ID: 98584).

The construct of emotions reflecting reality and perception of truth seems to be associated with experiencing emotions more vividly. The construct was found to be a crucial component of all CDs. In approximately half of the labeling posts, this construct could be seen as a continuation of category 1.3, in most of the cases following the construct of emotional states becoming rules: "I'm not a good friend. I'm fat and have a lot of scars from self-harm. I hate myself more and more. I think, this summer, I will kill myself before the end of my vacation." (ID: 227081).

Category 3. Impaired Ability to Shift Perspective Affective states accompanying negative self-evaluation are projected not only as an experience of reality but also as what others think. This construct appears as a continuation of the category 2 construct of experiencing emotional states as reality. The category 3 construct contains text passages displaying thoughts about what others think: "(…) both my friends say I don't understand them, and I think they are trying to tell me I'm stupid. How can I be a good and understanding friend, while also making them like me?" (ID: 262215).

Distributed between the CDs of labeling, emotional reasoning, and mindreading, we found a seemingly impaired ability to shift away from what is interpreted as depressive rumination. In some of the posts, this is stated directly: "I am never able to 'pull myself together' and avoid going out. I feel people see me as a fake, angry, uninterested, irritated, and rude. It's very tiring to think about what other people think of me." (ID: 176552).

Category 4. Shifting Focus In more than half of the posts and distributed between the CDs of labeling, emotional reasoning, and mindreading, this category represented the lack of ability to shift away from what is interpreted as depressive rumination, causing a negative cognitive spiral. In some of the posts, the disability to halt this kind of rumination is

stated directly: "I am never able to 'pull myself together' and avoid going out. I feel people see me as a fake, angry, uninterested, irritated, and rude. It's very tiring to think about what other people think of me." (ID: 176552).

The construct was present in all CDs except the CD of catastrophizing (Figure 2).

DISCUSSION

We found that the CDs consisted of implicit units of meaning representing common constructs of thoughts and emotional states. The constructs resembling the process of emotional reasoning penetrated all CDs found in the analysis. The constructs seemed to follow different variations in a pattern with possible neural presets.

1. Category 1: generalized beliefs possibly stemming from biased memory encoding and recall.
2. Category 2: experiencing emotional states stronger, representing a social reality.
3. Category 3: impaired ability to shift focus from first- to third-person perspective due to immature PFC and limbic functions.
4. Category 4: associated with immature ACC functions, struggling to escape the ensuing depressive rumination.

The category of generalizing beliefs, events, and emotional states showed similarities with a CD not found in this study: overgeneralization. This category could reflect an interplay between overgeneralized global beliefs associated with biased hippocampal memory recall[22] and the ensuing affective states of category 2. It is widely recognized that the interaction between an overgeneralized memory recall and the subsequent emotional state reflects a neurodynamic process rather than a stepwise activation of isolated brain functions in congruence with the fluctuating nature of depressive symptoms. The construct of generalization seemed intertwined with the CDs of labeling, emotional reasoning, and catastrophizing, resembling a tendency to generalize single events and the ensuing emotional states to future events.[17]

In a social context, the category of emotional states reflecting reality resembles in content and meaning the CD of emotional reasoning. The proposed neural feature is a relatively higher ventromedial PFC involvement in top-down

prefrontal limbic control during adolescence and depression, which is also associated with increased activity in the bottom-up pathways.[20–22,24] Amplified emotional perception in depressed adolescents could contribute to the experience of emotional states reflecting a social reality. If so, adolescents are prone to CDs originating from constructs resembling emotional reasoning. We could assume this from descriptions found about acting according to emotions such as self-disgust, social shame, and fear.

The findings suggest a process following the constructs of generalization, experiencing emotions to resemble a social reality. Adolescents with symptoms of depression seemed less agile in their attempts to shift attention away from depressive rumination, consistent with the findings of previous research on ACC maturation.[21]

Future research should investigate the efficacy of technological psychoeducation measures derived from different data sources, preferably using randomized controlled trial designs. Psychoeducation for use in conversational AI could aim at identifying underlying constructs of thoughts and informing about their depressogenic potential, the possible neural mechanisms behind, and the fact that they are prone to therapeutic reattribution. Artificial intelligence–based conversational agents, such as Woebot, are used by adults with depression.[11,14] The application of such technology has been shown to be helpful in adolescents.[11] In previous studies, AI models have been developed to identify posts describing symptoms of depression in large textual databases.[31] Further research should investigate possible beneficial and harmful consequences of using such tools.

By using large language machine learning models, we may train AI models to detect underlying constructs of meaning in AI conversations in which the model has already revealed possible symptoms of depression and ultimately provide relevant psychoeducation.

Limitations

Both raters are CBT physicians. There is a risk of overinterpretation, that is, reading the findings into data. To compensate, for every iteration, a code meeting was conducted, discussing alternative interpretations regarding preconceptions, language, and the effect of comorbidity. Both raters used their clinical experience to link the reading to real clinical situations.

Data consisted of posts written by adolescents in situations that made them post a question on a web service. Despite this selection, we believe this kind of data could provide a supplementary and unique insight into the life of adolescents with depressive symptoms.

Although such data may be less hampered by response bias, the posts are possibly influenced by what kind of reply the user expects. Confounders such as mood swings, comorbid psychiatric and physical conditions, and drug abuse could affect data quality.

The results of this study need to be interpreted with caution. Underlying constructs of thoughts are probably affected by complex psychological and neurobiological processes. As discussed earlier, the model proposed in this study could only work as a gateway for therapeutic and technological intervention.

CONCLUSION

The main clinical implication of this study is to promote awareness of and possibly challenge the constructs of thought representing the following:

1. Overgeneralized beliefs about oneself in relation to others and the future.
2. Emotional states appearing as reality.
3. Experiencing this emotional reality as something others think.

Rather than navigating on a wide range of CDs, those creating psychoeducation materials for use in conversational AI should concentrate on these specific constructs and the potential neural mechanisms involved.

POTENTIAL COMPETING INTERESTS

The authors report no competing interests.

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KKD designed the study, drafted the manuscript, reviewed relevant literature, participated in and led the analysis procedures. JIR contributed during the coding process and gave advice on cognitive behavioral theory and neuroscience. PBB and AF contributed to data collection through the original Social Health Bots project. All authors edited the manuscript and contributed on the final analysis meetings. ORH assisted in the preparation of the manuscript. AK coordinated and reviewed the manuscript and supervised the project. MS, ORH and AK applied additional advice about reporting text data extracts. All authors have read and approved the final manuscript.

Data sharing: External data validation will not be possible because the data, owing to user privacy issues, are withheld by the by owner: the Norwegian Directorate for family, adolescent, and child affairs. In some of the questions posted on the information website ung.no, the user declares full disclosure. For data validation, these posts must be extracted from the material. The rest of the posts are then available for validation after processing, although in Norwegian language. A request for a processed dataset can be submitted to the owner: beate.aas@bufdir.no or the Social Health Bots project manager p.b.brandtzag@media.uio.no.

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