**Supplementary Information**

**Automated Detection of Suicide Risk from Textual Facebook Activity: Data, Neural Network Models, and Language Usage Analysis**

\*Yaakov Ophir,1,2 Refael Tikochinski,1 Christa Asterhan,1 Itay Sisso,1 Roi Reichart2

1The Hebrew University of Jerusalem, 2Technion – Israel Institute of Technology

**Psycho-diagnostic tools**

**Major Depressive Disorder (MDD).** Major depression was measured using the Patient Health Questionnaire-9 (PHQ-9; Kroenke et al., 2001), a nine items scale that targets the nine symptoms of depression described in the DSM. Each item (symptom) is scored from 0 to 3 (not at all, several days, more than half the days, and nearly every day). The scale can be used both as a continuous measure (range = 0–27) of the severity of the depression and as a dichotomous measure to estimate the presence of depression (yes/no). The dichotomous cut-off point for the presence of depression corresponds with the DSM criteria and can be calculated when five or more symptoms receive a score of at least “more than half the days” and when these symptoms include one of the two key symptoms of depression: low interest and depressed mood (Spitzer et al., 1999). Given its well-established validity and high sensitivity and specificity, the PHQ-9 is preferred over all other screening tools for depression (El-Den et al., 2018). The internal consistency of the scale in the current sample was high (α = .90) and the correlation with suicide total scores was high (*r* = 0.46).

**Generalized Anxiety Disorder (GAD).** GAD was measured using a well-established, seven-item scale named GAD-7 (3). Each item, scored from 0 to 3 (not at all, several days, more than half the days, and nearly every day), targets one of the seven symptoms of the disorder. The total score of the scale (range 0 – 21) serves as an indication for both the existence and the severity of the disorder. According to the developers, the cutoff point for GAD is set to 10 points or higher (Spitzer et al., 2006). The internal consistency of the scale in the current sample was high (α = .92). The evidenced comorbidity between GAD and major depression as indicated in a bivariate Pearson, was very high (*r* = 0.76).

**Depressive rumination (Brooding).** Depressive rumination as mentioned above is a maladaptive pattern of thinking in which people focus on their depressive feelings and enter a repetitive loop of negative thoughts (Mor et al., 2014; Nolen-Hoeksema et al., 2008; Watkins, 2008). Specifically, the unconstructive component of this ruminative thinking, which has been shown to be strongly associated with depression was named “brooding” (Schoofs et al., 2010). Brooding was measured using five items rated from 1 (almost never) to 4 (almost always) from the frequently used Ruminative Responses Scale (RRS; Nolen-Hoeksema & Morrow, 1991). Respondents read a general statement about depressive events (“*People think and do many different things when they feel depressed*”) and are asked to indicate to what extent they engage in a given response. An example for a brooding response is: “*Think about a recent situation, wishing it had gone better*.” The internal consistency of the 5 brooding items, in the current sample was good (α = .82) and the correlation with depression was high (*r* = 0.62).

**Excessive worrying.** A second pattern of negative thinking is excessive and subjectively uncontrollable worries about the future (Brown et al., 1992). To assess excessive worrying patterns, we used the Penn State Worry Questionnaire (PSWQ; Meyer et al., 1990). The PSWQ is a well-established research tool (Fresco et al., 2003) that comprises 16 items, rated on a five-point scale (1 = not as all typical of me, 5 = very typical of me). The items address various aspects of pathological worry including its excessiveness (e.g., “*Many situations make me worry*”) and the subjective feeling of uncontrollability (e.g., “*Once I start worrying, I cannot stop*”). The internal consistency of the PSWQ in the current sample was high (α = .96) and the correlation with depression was high (*r* = 0.56).

**Loneliness.** Experiences of loneliness were measured using the 10-item version of the UCLA-Loneliness Scale (Russell, 1996). The items, rated from 1 (Never) to 4 (Always), encompass various aspects of loneliness experiences (e.g., “*How often do you feel that you lack companionship*”). This version of the scale demonstrated high levels of convergent validity and internal consistency (Elphinstone, 2018). The internal consistency of the scale in the current sample was high (α = .92) and the correlation with depression was high (*r* = 0.60).

**Low satisfaction with life.** The general sense of satisfaction with life was measured using the Satisfaction With Life Scale (SWLS); Diener et al., 1985). This short scale comprises five items, rated from 1 (strongly disagree) to 7 (strongly agree). All items are formulated in a positive manner (e.g., “*The conditions of my life are excellent*”). Although we were interested in low satisfaction with life, we kept the original positive style of the scale to “break” the overall negative atmosphere of the research and to promote participants’ attentiveness along the research. The SWLS demonstrated good psychometric characteristics (Pavot & Diener, 2009) and moderate-strong negative relationships with depression (Blais et al., 1989; Schimmack et al., 2004). The internal consistency of the scale in the current sample was high (α = .93) and the negative correlation of this positive scale with depression was high (*r* = –0.53).

**Personality traits.** Personality traits were assessed using the short version of the Big Five Inventory (BFI; Rammstedt & John, 2007). The BFI-10 includes ten items that target the five clusters of personality traits, originally formulated in the standard 44-item BFI: Extraversion, Neuroticism, Openness to Experience, Agreeableness and Conscientiousness (John & Srivastava, 1999). Each trait in the BFI-10 is measured by only two items that are rated from 1 (disagree strongly) to 5 (agree strongly). The BFI-10 achieved high levels of reliability and validity (Rammstedt & John, 2007) and is currently widely used in research settings. Consistent with the literature on depression, the correlation between the personality trait of neuroticism and depression was high (*r* = 0.51).

The convergent validity of the psychosocial scales was high. As expected, the total score of the suicide scale was positively correlated with all the risk factors examined in the study and especially with depression (*r* = 0.46). Consistent with the literature on depression described above, the comorbidity between depression and anxiety was very high (*r* = 0.76) and the four psychosocial risk factors (i.e., brooding, excessive worry, loneliness, and low satisfaction with life) were strongly correlated with depression (Pearson’s *r* ranging from 0.53 to 0.62). The personality trait of neuroticism was also strongly correlated with depression (*r* = 0.51).

**Ethical considerations**

Crowdsourcing-based suicide research involves an ethical challenge: how to safeguard the well-being of suicidal participants, without the possibility of face-to-face interactions? To address this ethical challenge, we adhered to an online suicide research protocol developed recently by an expert consortium (Ophir et al., under review). Prior to consenting to participate in the study, participants were informed that if their responses would indicate some form of suicidal risk, we would contact them through the data collection platform. Each participant who met the CSSRS criterion for general suicide risk (i.e., suicidal thoughts with or without a specific method or a concrete plan) then received a designated letter in which we encouraged them to seek help and provided them with a list of available “hot-lines” and national mental health services. The complete description of the protocol and the ethical considerations made in the current research are available upon request.

**ANN-based models – parameter estimation (learning)**

The optimization of the model was conducted with batch sub-gradient descent (batch-size of 32), using the back-propagation algorithm (Goodfellow et al., 2016) and the RMSProp optimizer (Tieleman & Hinton, 2012) with a momentum parameter of 0.9. The hyper-parameters of the models were tuned using a grid-search method. These hyper-parameters included the number of fully connected layers {1, 2, 3},[[1]](#footnote-1) the number of neurons in each layer {16, 32, 64, 128, 256, 512, 1024}, and the type of the activation function {*hyperbolic tangent*, *sigmoid*}. The hyper-parameters of the optimization algorithm were the learning rate {0.001, 0.005, 0.01, 0.05}, and the number of epochs {1000, 2500, 5000}.

The final hyper-parameters of the STM included: 3 fully connected layers, 32 neurons, an activation function of *hyperbolic tangent*, a learning rate of 0.01 with 2,500 epochs. The final hyper-parameters of the MTM included: 2 fully connected layers, 16 neurons, an activation function of *hyperbolic tangent*, a learning rate of 0.001 with 5,000 epochs.

**References**

Blais, , Vallerand, , Pelletier, ,& Brière, (1989). L’échelle de satisfaction de vie: Validation canadienne-française du “Satisfaction with Life Scale.” *Canadian Journal of Behavioural Science/Revue canadienne des sciences du comportement*, *21*, 210.

Brown, , Antony, ,& Barlow, D. H. (1992). Psychometric properties of the Penn State Worry Questionnaire in a clinical anxiety disorders sample. *Behaviour Research and Therapy*, *30*, 33–37.

Diener, ,Emmons, ,Larsen, , &Griffin, S. (1985). The satisfaction with life scale. *Journal of Personality Assessment*, *49*, 71–75.

Elphinstone, (2018). Identification of a suitable short‐form of the UCLA‐Loneliness Scale. *Australian Psychologist*, *53*, 107–115.

Fresco, ,Mennin, ,Heimberg, , &Turk, (2003). Using the Penn State Worry Questionnaire to identify individuals with generalized anxiety disorder: A receiver operating characteristic analysis. *Journal of Behavior Therapy and Experimental Psychiatry*, *34*, 283–291.

Goodfellow, , Bengio, Y., & Courville, A. (2016). *Deep learning*. Cambridge, MA: MIT Press.

John, , &Srivastava, S. (1999). The Big Five Trait taxonomy: History, measurement, and theoretical perspectives. In (),*Handbook of personality: Theory and research* (2nd edition)*.* New York: Guilford Press (pp. 102–138.20).

Kroenke, K., Spitzer, R. L., & Williams, J. B. W. (2001). The PHQ-9: Validity of a brief depression severity measure. *Journal of General Internal Medicine*, *16*, 606–613.

Meyer, ,Miller, , Metzger, , &Borkovec, (1990). Development and validation of the Penn State Worry Questionnaire. *Behaviour Research and Therapy*, *28*, 487–495.

Mogotsi, I.C., Manning, C. D., Raghavan, P., & Schütze, H. (2010). Introduction to information retrieval. *Information Retrieval*, *13*, 192–195.

Mor, N., Hertel, P., Ngo, T. A., Shachar, T., & Redak, S. (2014). Interpretation bias characterizes trait rumination. *Journal of Behavior Therapy and Experimental Psychiatry*, *45*, 67–73.

Nolen-Hoeksema, S., & Morrow, J. (1991). A prospective study of depression and posttraumatic stress symptoms after a natural disaster: The 1989 Loma Prieta earthquake. *Journal of Personality and Social Psychology*, *61*, 115–121.

Nolen-Hoeksema, S., Wisco, B. E., & Lyubomirsky, S. (2008). Rethinking rumination. *Perspectives on Psychological Science*, *3*, 400–424 .

Ophir, ,et al. (Under review). The ethics of suicide research online: A consensual protocol for crowdsourcing-based studies on suicide

Pavot, W., & Diener, E. (2009). Review of the satisfaction with life scale. In *Assessing well-being*. New York: Springer (pp. 101–117).

Rammstedt, ,& John, Measuring personality in one minute or less: A 10-item short version of the Big Five Inventory in English and German. *Journal of Research in Personality*, *41*, 203–212.

Russell, D. W. (1996). UCLA Loneliness Scale (Version 3): Reliability, validity, and factor structure. *Journal of Personality Assessment*, *66*, 20–40.

Schimmack, U., Oishi, S., Furr, R. M., & Funder, D. C. (2004). Personality and life satisfaction: A facet-level analysis. *Personality and Social Psychology Bulletin*, *30*, 1062–1075.

Schoofs, H., Hermans, D., & Raes, F. (2010). Brooding and reflection as subtypes of rumination: Evidence from confirmatory factor analysis in nonclinical samples using the Dutch Ruminative Response Scale. *Journal of Psychopathology and Behavioral Assessment*, *32*, 609–617.

Spitzer, R. L., Kroenke, K., & Williams, J. B. W. G. (1999). Patient Health Questionnaire primary care study, validation and utility of a self-report version of PRIME-MD: the PHQ primary care study. *Journal of the American Medical Association*, *282*, 1737–1744.

Spitzer, R. L., Kroenke, K., Williams, J. B. W., & Löwe, B. (2006). A brief measure for assessing generalized anxiety disorder: The GAD-7. *Archives of Internal Medicine*, *166*, 1092–1097.

Tieleman, T., and Hinton., G. (2012). Lecture 6.5-rmsprop: Divide the gradient by a running average of its recent magnitude. *COURSERA: Neural networks for machine learning*, 4, no. 2: 26–31.

Watkins, E. R. (2008). Constructive and unconstructive repetitive thought. *Psychological Bulletin*, *134*, 163.

1. Note that all the sub-networks of the MTM had the same number of fully connected layers. [↑](#footnote-ref-1)