Machine learning-based measurement of delusional dreaming

Calvin Kai-Ching Yu

Department of Counselling and Psychology, Hong Kong Shue Yan University, Hong Kong

Summary. This study investigated the prevalence of delusion sentiment in dreams using machine learning-based measurement. Classification models were developed by training the SVM (support-vector machine) algorithm with 841 words relevant to grandiose delusions and 978 words relating to persecutory delusions. They were then utilized to score grandiose and persecutory sentiment in 2611 dreams primarily obtained from an open source, including dreams reported by American, Chinese, German, and Peruvian people. The classification accuracy of the SVM model for detecting grandiose words was 86.4%, that for detecting persecutory words being 97.6%. The prevalence rates of dream reports being classified by the SVM algorithms as grandiose and persecutory dreams in the entire dream collection were 12.2% and 11.2%, respectively. Overall, around a quarter of dreams exhibited delusional content, which is more prevalent than the epidemiological estimate of psychosis in waking life – that is, approximately 0.3% worldwide. Given its fine-grained scoring, cost-efficiency, and absence of subjective judgment, the SVM method can be a useful tool for coding delusional sentiment in dreams.

Keywords: Automated content analysis, dream delusion, machine learning, sentiment analysis, support-vector machine

1. Introduction

Researchers have employed various automated algorithms to code dream reports, such as Linguistic Inquiry and Word Count (LIWC; Bulkeley & Graves, 2018; Niederhoffer, Schler, Crutchley, Loveys, & Coppersmith, 2017; Zheng & Schweickert, 2021, 2023), support vector machines constructed using LIWC word counts (Zheng & Schweickert, 2023), word count analyses (Stiles, Frazier, & Eddington, 2023), and self-developed tool that automatically scores dream reports based on Hall and Van de Castle's coding system (Fogli, Maria Aiello, & Quercia, 2020). These algorithms are designed to be comprehensive, covering various aspects of dream reports. For instance, the LIWC can quantify words used to express emotions and cognitive processes in a dream report. Similarly, Fogli et al.'s (2020) tool encompasses three key categories of Hall and Van de Castle's coding system: dream characters, social interactions, and emotions. However, no automated scoring technique has yet been developed to evaluate a specific aspect of dreaming – namely, delusional ideation.

Dreaming has been conceived as an altered state closely akin to psychosis since Freud's (1900) discussion of the suspended self-consciousness, delusional material, and hallucinatory regression of dreams in his seminal book *The Interpretation of Dreams*. After more than a century, this theoretical isomorphism between dreaming and psychosis still sustains and has been empirically tested by comparing dream content with psychotic or waking thoughts. Hobson's research group (Hobson, Hoffman, Helfand, & Kostner, 1987; Mamelak & Hobson, 1989) developed a scale for rating the bizarreness of dream content. Their scale assesses the physical improbability of dream plot, cognition, and affect along three dimensions: discontinuities, incongruities, and uncertainties. In a study using this scale, Williams, Merritt, Rittenhouse, and Hobson (1992) found that bizarreness was far more prevalent in dreams than in waking fantasies. Furthermore, Scarone et al.'s (2008) study demonstrated that dreams reported by both ordinary participants and schizophrenics were characterized by a similar level of bizarreness as schizophrenics' waking fantasies.

Many theories have been postulated to explain the psychotic features of dreams, such as dreaming as a storytelling instinct (Pace-Schott, 2013) and a felt presence associated with rapid-eye-movement (REM) sleep (Cheyne & Girard, 2007). These theories have been anchored to distinct, yet closely related, neural mechanisms of REM dreaming, for example, a lack of connectivity between the dorsomedial prefrontal subsystem and the posterior central node of the default network in the posterior cingulate (Koike et al., 2011; see also Pace-Schott, 2013), loss of antero-posterior EEG synchrony in the gamma frequencies during REM sleep (Corsi-Cabrera et al., 2003, 2008; see also Pace-Schott, 2013), neuronal bifurcations caused by phasic discharge of pontogeniculooccipital neurons during REM sleep (Mamelak & Hobson, 1989), REM initiation of a threat activated vigilance system (Cheyne & Girard, 2007), and the neurodynamics of compromised censorship, topographic regression, and temporal regression (Solms, 1997; Yu, 2001a, 2001b, 2003, 2006).

Notwithstanding the numerous theories and models, it is widely accepted that the disengagement of the reality testing or self-reflective function, associated with the inactivity in the prefrontal cortex, underlies both dreaming and

Corresponding address:
Calvin Kai-Ching Yu, Department of Counselling and Psychology, Hong Kong Shue Yan University, 10 Wai Tsui Crescent, Braemar Hill Road, North Point, Hong Kong.
Email: kcyu@hksyu.edu

Submitted for publication: April 2023
Accepted for publication: September 2023
DOI: 10.11588/ijodr.2023.2.94934

psychosis (Gottesmann, 2006). In connection with this, the phenomenon of lucid dreaming, which is distinguished by the dreamer's awareness of being in a dream, poses a paradox for researchers – that is, dreaming with preserved self-reflection. In other words, lucid dreams are dreams that lack the crucial characteristic of dreams. If the suspension of the self-reflective function, one way or another, causes the bizarreness of dream content, it is reasonable to hypothesize that psychometric measures of self-reflection and insight should inversely vary with the rating of dream bizarreness and that lucid dreams should be less bizarre than their non-lucid counterparts. Yu and Shen (2020) conducted a study to test these hypotheses. Their findings supported both hypotheses. In relation to this, Dresler et al. (2015) noted that the brain regions activated during lucid dreaming are often the same regions found to be impaired in psychotic patients who are unaware of their pathological condition. This observation suggests that similar neural correlates are responsible for the development of insight into both the dreaming and psychotic states.

Despite the ample evidence for the bizarreness of dream content, meagre efforts have been made to examine delusional material of dreams. Mason and Wakerley (2012) assessed participants' psychotomimetic features during dreaming and wakefulness. The experience of dreaming was rated by their participants to be more psychotic-like than waking life, especially in their ratings of paranoia and delusional thinking. Similarly, Yu's (2009a, 2009b, 2010) evidence repeatedly demonstrated that virtually all types of delusions and paranoid suspiciousness can be observed in dreams. For example, the dream themes of being chased or pursued (87.3%), exerting magical powers (63.1%), having a love affair with a celebrity (53.5%), possessing superior knowledge or mental ability (52.2%), and being spied on or talked about (52%) were found to be very common, with the prevalence of over 50% in Yu's (2010) sample. Additionally, his exploratory and confirmatory analyses replicated the three-factor model for classifying typical dream themes. Consistent with the homology between dreaming and psychosis, the first two clusters of dream themes were characterized by grandiose and persecutory delusions.

Indeed, grandiosity and persecution can both be considered as types of sentiment within the context of mental health conditions. Sentiment refers to the overall attitude expressed in a piece of text or speech. In the case of grandiosity, the delusional belief in one's superiority or importance can be seen as a positive sentiment in the sense that it reflects a positive view of oneself. Conversely, in the case of persecution, the delusional belief that one is being unfairly targeted or persecuted can be seen as a negative sentiment to the effect that it reflects a negative view of others or society. Studying grandiose and persecutory delusions as sentiments in dreams can facilitate the measurement of delusional qualities of dreams. Specifically, although grandiose and persecutory themes can cooccur in a dream, it can be determined whether the dream is more pertinently classified as grandiose or persecutory by also considering the predominant polarity of the dream sentiment.

It is difficult to quantify the severity of delusion of a dream, even with the assistance of trained raters. However, sentiment with delusional implications can be readily measured. The support-vector machine (SVM; Boser, Guyon, & Vapnik, 1992 Cortes & Vapnik, 1995) is a popular machine-learning algorithm for solving a classification problem. Yu (2022b) demonstrated that automated algorithms can be effectively used for scoring dream sentiment. Specifically, SVM can generate scores to indicate the intensity of positive or negative sentiment of a dream. For example, SVM sentiment scores range from $-\infty$ to $+\infty$, with a score larger than 0 indicating positive sentiment and a score close to 0 corresponding to neutral sentiment.

This automated approach to sentiment analysis typically hinges on a lexicon. Yu built a SVM model by training the algorithm with Hu and Liu's (2004) lexicon. Of the 4783 negative sentiment words encompassed in Hu and Liu's (2004) lexicon, 646 are highly relevant to persecutory delusion, such as butcher, devil, massacre, monster, and persecute. On the other hand, 279 of the 2006 positive sentiment words in the lexicon have direct implications for grandiose delusion, such as admirer, angel, enchant, magical, and prodigious.

Accordingly, similar machines can be created via training with these sentiment words and the like to assess the intensity of dream delusion along a fine-grained continuum. Dreaming has long been conceived as a psychotomimetic state. There has been no study assessing delusional sentiment in dreams. The application of such machines in scoring a large, representative sample of dreams can determine the prevalence of delusional ideation in dreams and provide further evidence for the homology between dreaming and psychosis. Therefore, the study presented here was carried out to develop automated assessment of dream delusion and to investigate the prevalence of delusion sentiment in average dreams.

Affective experiences during dreaming are sometimes complicated, with mixed feelings that dreamers might find difficult to express. Yu (2022b) argued that a discrepancy between manual and automated rating methods does not necessarily indicate a reliability issue but exposes dream dynamics that deserve further exploration. Although manual scoring of the intensity of dream delusion is subjective and very challenging even for a professional rater, delusional themes can be readily coded by trained raters in accordance with the Dream Motif Scale (Yu, 2015, 2022a). Delusional themes coded by external judges were juxtaposed with the level of delusional sentiment scored by automated machines to identify issues concerning manual and automated scoring.

Specifically, it was hypothesized that dream reports with manually coded grandiose themes have a larger SVM grandiosity score but a smaller SVM persecution score than do those without manually coded grandiosity themes. On the other hand, dream reports with coded persecutory themes would show a larger SVM persecution score but a smaller SVM grandiosity score than would those reports without coded persecutory themes.

2. Method

2.1. Samples

Normative dream reports were retrieved from the dream bank established by Domhoff and Schneider (2008; www.dreambank.net, Schneider & Domhoff, n.d). These included 981 American dreams (490 female dreams; Hall & Van de Castle, 1966), 661 German dreams (491 female dreams; Schredl et al., 2003), and 766 Peruvian dreams (382 female dreams; Urbina & Grey, 1975). In addition to these Western

dreams, 100 Hong Kong dreams (75 female dreams) and 103 Taiwanese dreams (86 female dreams) were included in the present study. This gave a total of 2611 dreams. Peruvian dreams retrieved from the dream bank are available in English. German and Chinese dreams were translated into English by Google Translate before analysis. The translated dreams were checked by assistants proficient in Chinese, English, and German.

2.2. SVM Analysis of Dream Delusion

The sentiment of dreams was classified using Support Vector Machine (SVM) in MATLAB. The SVM classification employed a radial basis function (RBF) kernel, with a regularization parameter (C) set to 1, kernel scale (sigma) automatically chosen based on the data, and box constraint set to "inf" (no upper bound on the magnitude of coefficients). RBF kernel is known for its ability to model complex decision boundaries and handle non-linearly separable data. Dream reports were preprocessed by using a pre-trained word embedding package (fastText English 16 Billion Token Word Embedding support package), followed by tokenization, removal of punctuation, stop words (such as "of" and "the"), and words not present in the word embedding package.

The present author compiled a wordlist by searching for words related to grandiose themes illustrated by the DSM-5-TR (American Psychiatric Association, 2022) and the Dream Motif Scale (Yu, 2012) in six thesauruses, including Cambridge Dictionary English Thesaurus (https://dictionary.cambridge.org/thesaurus/), Collins English Thesaurus (https://www.collinsdictionary.com/dictionary/english-thesaurus), Merriam-Webster (https://www.merriam-webster.com/), New American Roget's College Thesaurus in Dictionary Form, Oxford Thesaurus: An AZ Dictionary of Synonyms, and Theasurus.com (https://www.thesaurus.com/). The list was then reviewed and revised based on feedback from a clinical psychologist with over 20 years of experience. A total of 841 words relevant to grandiose delusion

Figure 1. Grandiose Words in the Lexicon.
Note. A larger font indicates a larger individual grandiosity score.

Figure 2. Persecutory Words in the Lexicon.
Note. A larger font indicates a larger individual persecution score.

were identified from the six thesauruses. A SVM model was built up by training the algorithm with this wordlist together a list of 4783 negative sentiment words extracted from Hu and Liu's (2004) lexicon. In a similar vein, 978 words relating to persecutory delusions were identified from the thesauruses. Another SVM model was built up by training the algorithm with these persecutory words and a list of 2006 positive sentiment words extracted from Hu and Liu's lexicon.

A tenth of words was randomly set aside for testing the classification accuracy of the two trained SVM models. The tested SVM models were then employed to score the grandiosity and persecution levels of each dream. The sentiment level of each annotated word of a dream report was scored – that is, the confidence level of the word belonging to the class or the distance of the word to the hyperplane in the SVM model that separated that class from the others. The SVM grandiosity/persecution score was an average of grandiosity/persecution scores of all annotated words of the dream report. SVM sentiment scores range from -∞ to +∞, with a score larger than 0 indicating positive sentiment and a score close to 0 corresponding to neutral sentiment.

Dream grandiosity and persecution were defined by both their unusual convictions and sentiments. To evaluate the validity of dream delusion detected by the automated algorithms, the SVM grandiosity and persecutory scores were compared against the external judges' coding of grandiose and persecutory themes. It was anticipated that the SVM grandiosity score would be larger in those dreams with manually coded grandiose themes.

2.3. Human Ratings

The Dream Motif Scale (DMS; Yu, 2012) comprises 15 categories of dream themes. The DMS Grandiosity category contains 20 dream themes which are comparable to grandiose delusions commonly observed in psychosis, such as encountering a deity in some form, becoming a celebrity or

Figure 3. Grandiose Words in Dream Content.
Note. A larger font indicates a larger individual grandiosity score.

an important person, and having magical powers. The Persecution category encompasses 20 dream themes suggestive of persecutory delusions, such as encountering a devil in some form, being spied on or talked about, and being pursued. Each of the 203 Chinese dreams were independently coded by two undergraduate raters in accordance with the two DMS categories. A postgraduate rater verified all coded dreams and made a judgement for disagreements between the two undergraduate raters.

3. Results

Of the 81 grandiose words randomly selected for testing the classification accuracy, 70 (86.4%) was correctly predicted by the trained SVM model. The SVM persecution model was similarly distinguished by its very high accuracy rate – that is, 83 (97.6%) of 85 persecutory words. Figures 1 and 2 present some grandiose and persecutory words identified by the trained SVM model in the lexicon, respectively. *Acclaimed, crowning, superlative, superhuman*, and *unrivalled* were the strongest grandiose words among the 518 words for testing, *bloody, disfigured, frightful, ill-treatment*, and *persecution* being the most robust persecutory words. Figures 3 and 4 present some grandiose and persecutory words identified by the SVM in the 2611 dream reports, respectively. *Achieved, achievement, gift, gymnastic*, and *incomparable* were relatively strong grandiose words among the 2611 dreams, *disfigured, gored, misshapen*, and *snarled* being the strongest persecutory dream words.

3.1. Prevalence of Grandiose and Persecutory Dreams

The mean SVM grandiosity and persecution scores were -26.627 (*SD* = 2.870; Range = -236.522 - 52.468) and -23.216 (*SD* = 2.414; Range = -228.840 - 44.849), respectively. As indicated by their positive values, 319 (12.2%) of the 2611 dreams were classified as grandiose dreams, 293 (11.2%) being classified as persecutory dreams. Kolmogorov-Smirnov tests showed that both the grandiosity (D = 4.692, p < .001) and persecution (D = 4.392, p < .001) scores did not follow a normal distribution.

3.2. Cross-cultural and Sex Differences in Dream Grandiosity and Persecution

There were significant differences in the SVM grandiosity (Kruskal-Wallis test; χ^2 = 106.608, p < .001, $\mathcal{E}^2$ = 0.0225) and persecution scores (χ^2 = 58.624, p < .001, $\mathcal{E}^2$ = 0.0408) across the four samples. Both the SVM grandiosity (1472.12) and persecution mean ranks (1450.64) of the German sample were the highest, those of the Chinese sample being the lowest (1192.41, 1013.96). The sex difference in the SVM grandiosity score was significant but very small (Mann-Whitney U-test; U = 784271, p = .02, r = 0.0531). The same applied to the SVM persecution score (U = 765682, p < .001, r = 0.0756).

3.3. Comparison of SVM Delusional Scores and Manual Coding in Chinese Dreams

There were no significant differences in the SVM grandiosity (Mann-Whitney U-test; U = 2790, p = 0.963, r = 0.005) and persecution scores (U = 3014, p = 0.500, r = -0.075) between Chinese dream reports with manually coded grandiose themes and those without manually coded grandiosity themes. On the other hand, Chinese dream reports with coded persecutory themes showed a significantly larger SVM persecution score (U = 2425, p < .001, r = 0.435) and a significantly smaller SVM grandiosity score (U = 6697, p < .001, r = -0.561) than did those reports without coded persecutory themes.

Figure 4. Persecutory Words in Dream Content.
Note. A larger font indicates a larger individual persecution score.

Examples of dreams with relatively large grandiose (Appendices A-C) and persecutory scores (Appendices D-F) are provided in appendices. Of the 203 Chinese dreams, 16 (7.9%) were identified by the SVM as a grandiose dream but received no codes from raters. The average mean SVM grandiose score for these 16 dreams was 11.555 (*SD* = 9.722; Range = 0.350 - 36.680). As suggested by their moderate SVM grandiosity score, these dreams characterized by upbeat sentiment but subtle wish-fulfilment or enhancement of status, ability, or power, such as flying around a castle, mastering challenges with ease, and being allied with a celebrity, a person in power, or an unusual creature. Appendices G-I provide three examples of these dreams.

On the other hand, 25 (12.3%) grandiose dreams were classified by raters but not by the SVM. The average mean SVM grandiose score for these 25 dreams was -68.047 (*SD* = 6.792; Range = -194.791 – -1.757). These dreams showed some themes of DMS grandiosity category, such as meeting a celebrity or famous person, living in movie or digital game story, traveling to a different part of the universe, rescuing some people, and using psychokinetic power to create a proactive shield or move a vehicle. However, they were invariably imbued with negative moods, such as disgraceful attitude expressed by a celebrity, being betrayed by a lover, and being haunted by demons and ghosts. Appendices J-L present three examples of these dreams.

4. Discussion

This study created two learning SVM machines for assessing delusion sentiment (grandiosity and persecution) and investigated the prevalence of delusion sentiment in average dreams. A total of 2611 normative dreams were scored by the SVM algorithms. SVM delusional sentiment scores were juxtaposed with delusional themes coded by external judges. The comparisons of the SVM grandiosity and persecution scores against manually coded persecutory themes are consistent with the hypotheses. However, the comparisons between the SVM grandiosity and persecution scores and manually coded grandiose themes are not. While the evidence suggests that the SVM algorithm can accurately score dream persecution, caution should be exercised when interpreting SVM scored dream grandiosity. In other words, the current SVM algorithm for scoring dream grandiosity needs to be refined or supplemented with other coding methods. A caveat, however, is that manual rating, even conducted by well-trained raters, is not necessarily more accurate than automated scoring.

Further examination of the discrepancies between manual coding of grandiose themes and SVM scoring suggests that grandiose delusions in the form of subtle wish-fulfilment or enhancement of status, ability, or power are relatively difficult for external raters to identify. Moreover, there exist some dreams that feature grandiose themes, yet being imbued with negative sentiment, for example, being slighted by a celebrity and being attacked by a deity. On the other hand, persecutory delusion appears to be more consistently recognized by both SVM algorithms and human judges, perhaps, partly because of the less ambivalent experience. The accuracy rates for using the trained SVM models to identify grandiose and persecutory words were high – that is, 86.4% and 97.6%, respectively. Taken together, it appears that SVM could be an effective method for scoring delusional sentiment in dreams.

It is challenging for human raters without clinical background to judge whether a dream element is delusional. In this study, raters followed a predetermined set of themes. It should be noted that some DMS themes of the grandiosity category – such as rescuing some people, living in movie or digital game story, and traveling to a different part of the universe – are statistically associated with classic grandiose themes in Yu's (2009a, b, 2010) studies but they alone do not necessarily form grandiose delusions. In other words, those themes can transpire in a non-delusional fashion. Since nonprofessional raters can only code in accordance with a preset category of dream themes rather than judging the overall delusional plot of a dream, it is extremely expensive to manually code every dream in a way that the SVM does. Accordingly, automated scoring is a more viable option for studies that require fine-grained ratings.

Several studies (e.g., Fogli et al., 2020; Stiles et al., 2023; Zheng & Schweickert, 2021) have suggested that automated scoring can serve as a viable alternative to laborious hand coding. Nonetheless, the comprehensive review of applying automated text analysis to dreams by Elce, Handjaras, and Bernardi (2021) argued that existing automated scoring techniques cannot fully replace manual scoring due to inadequacies in validation. As Elce et al. argued, the SVM models developed in the present study are only intended for preliminary testing. Further development is necessary before automated scoring can fully replace manual scoring. Additionally, despite certain similarities, dream and psychotic states are characterized by distinct features. For instance, dreams are primarily visual and are often forgotten, whereas schizophrenic hallucinations are predominantly auditory and are frequently vividly recalled (refer to Waters et al., 2016, for a detailed comparison). Therefore, it might be beneficial to develop specific SVM models tailored to assessing dream delusions, rather than building them upon delusional themes observed in psychosis.

It is worth noting that the direct word search technique can supplement the SVM method to ensure that grandiose dream elements are not overlooked. This can be easily implemented using word processing software. For instance, in the current study, the words *god*, *devil*, *ghost*, and *monster* were found in 14, 2, 8, and 24 dream reports, respectively. Based on these numbers, it appears that delusional themes rarely occur in dreams. Unlike the direct word search method, the SVM method can identify relevant words beyond a fixed lexicon. The prevalence rates of grandiose and persecutory dreams classified by the SVM algorithms were 12.2% and 11.2%, respectively. Altogether, delusional sentiment was detected in approximately a quarter of the dreams. Although this prevalence rate may still be lower than expected if the homology between dreaming and psychosis is true, it is higher than the incidence of psychosis in daily life.

Charlson et al.'s systematic review (2018) suggested that schizophrenia is not a common disorder, with an estimated global prevalence rate of 0.28%. Their review surmised, furthermore, that China has the highest prevalence of schizophrenia (0.42%), whereas the prevalence rates of Europe and South America – including countries such as Germany and Peru – are relatively low (ranging from 0.16 to less than 0.27%). In the study presented here, the SVM grandiosity and persecution scores of both the German and Peruvian samples were higher than those of the Chinese sample. This finding contrasts sharply with the cross-country differences in the prevalence rates of schizophrenia estimated

by Charlson et al. However, it is important to note that the current findings should be replicated through more rigorous research. Future research could focus on examining cultural variations in dream delusions and their associations with waking delusions. By assessing the bizarreness of both waking and dream thoughts, a clearer understanding of the analogous relationship between dreaming and psychosis might be achieved.

References

American Psychiatric Association. (2022). Diagnostic and statistical manual of mental disorders (5th ed., text rev.). https://doi.org/10.1176/appi.books.9780890425787

Boser, B. E., Guyon, I., & Vapnik, V. N. (1992). A training algorithm for optimal margin classifiers. In Proceedings of the Fifth Annual Workshop of Computational Learning Theory, 5, 144-152, Pittsburgh, ACM.

Bulkeley, K., & Graves, M. (2018). Using the LIWC program to study dreams. Dreaming, 28(1), 43–58. https://doi.org/10.1037/drm0000071

Charlson, F. J., Ferrari, A. J., Santomauro, D. F., Diminic, S., Stockings, E., Scott, J. G., McGrath, J. J., & Whiteford, H. A. (2018). Global epidemiology and burden of schizophrenia: Findings from the global burden of disease study 2016. Schizophrenia Bulletin, 44(6), 1195–1203. https://doi.org/10.1093/schbul/sby058

Cheyne, J. A., & Girard, T. A. (2007). Paranoid delusions and threatening hallucinations: A prospective study of sleep paralysis experiences. Consciousness and Cognition: An International Journal, 16(4), 959–974. https://doi.org/10.1016/j.concog.2007.01.002

Cortes, C., & Vapnik, V. N. (1995). Support-vector networks. Machine Learning, 20 (3), 273–297.

Dresler, M., Wehrle, R., Spoormaker, V. I., Steiger, A., Holsboer, F., Czisch, M., & Hobson, J. A. (2015). Neural correlates of insight in dreaming and psychosis. Sleep medicine reviews, 20, 92–99. https://doi.org/10.1016/j.smrv.2014.06.004

Elce, V., Handjaras, G., & Bernardi, G. (2021). The Language of Dreams: Application of linguistics-based approaches for the automated analysis of dream experiences. Clocks and Sleep, 3(3), 495–514. https://doi.org/10.3390/clockssleep3030035

Fogli, A., Maria Aiello, L., & Quercia, D. (2020). Our dreams, our selves: Automatic analysis of dream reports. Royal Society open science, 7(8), 192080. https://doi.org/10.1098/rsos.192080

Freud, S. (1900). The interpretation of dreams. In J. Strachey (Ed.), The standard edition of the complete psychological works of Sigmund Freud (Vol. 4-5). London, UK: Hogarth Press, 1953.

Gottesmann C. (2006). The dreaming sleep stage: a new neurobiological model of schizophrenia? Neuroscience, 140(4), 1105–1115. https://doi.org/10.1016/j.neuroscience.2006.02.082

Hall, C. S., & Van de Castle, R. L. (1966). The content analysis of dreams. New York: Appleton-Century-Crofts.

Hobson, J. A., Hoffman, S. A., Helfand, R., & Kostner, D. (1987). Dream bizarreness and the activation-synthesis hypothesis. Human Neurobiology, 6(3), 157–164.

Hu, M., & Liu, B. (2004). Mining and summarizing customer reviews. Proceedings of the ACM SIGKDD International Conference on Knowledge Discovery and Data Mining (KDD-2004). Seattle, Washington, USA. Aug 22-25, 2004.

Koike, T., Kan, S., Misaki, M., & Miyauchi, S. (2011). Connectivity pattern changes in default-mode network with deep non-REM and REM sleep. Neuroscience research, 69(4), 322–330. https://doi.org/10.1016/j.neures.2010.12.018

Mamelak, A. N., & Hobson, J. A. (1989). Dream bizarreness as the cognitive correlate of altered neuronal behavior in REM sleep. Journal of Cognitive Neuroscience, 1(3), 201–222. https://doi.org/10.1162/jocn.1989.1.3.201

Mason, O., & Wakerley, D. (2012). The psychotomimetic nature of dreams: an experimental study. Schizophrenia Research and Treatment, 2012, 872307. https://doi.org/10.1155/2012/872307

Niederhoffer, K., Schler, J., Crutchley, P., Loveys, K., & Coppersmith, G., (2017). In your wildest dreams: the language and psychological features of dreams. In Proceedings of the Fourth Workshop on Computational Linguistics and Clinical Psychology — From Linguistic Signal to Clinical Reality, 13–25, Vancouver, BC. Association for Computational Linguistics.

Pace-Schott E. F. (2013). Dreaming as a story-telling instinct. Frontiers in Psychology, 4, 159. https://doi.org/10.3389/fpsyg.2013.00159

Scarone, S., Manzone, M. L., Gambini, O., Kantzas, I., Limosani, I., D'Agostino, A., & Hobson, J. A. (2008). The dream as a model for psychosis: an experimental approach using bizarreness as a cognitive marker. Schizophrenia Bulletin, 34(3), 515–522. https://doi.org/10.1093/schbul/sbm116

Schredl, M., Petra, C., Bishop, A., Golitz, E., & Buschtons, D. (2003). Content analysis of German students' dreams: Comparison to American findings. Dreaming, 13(4), 237-243.

Solms, M. (1997). The neuropsychology of dreams: A clinico-anatomical study. Lawrence Erlbaum Associates Publishers.

Stiles, L., Frazier, A. & Eddington, K.M. (2023). What were you thinking? A comparison of rater coding and word counts for content analysis of thought samples in Depression. Journal of Rational-Emotive and Cognitive-Behavior Therapy, https://doi.org/10.1007/s10942-023-00507-0

Urbina, S. P., & Grey, A. (1975). Cultural and sex differences in the sex distribution of dream characters. Journal of Cross-Cultural Psychology, 6(3), 358-364.

Waters, F., Blom, J. D., Dang-Vu, T. T., Cheyne, A. J., Alderson-Day, B., Woodruff, P., & Collerton, D. (2016). What is the link between hallucinations, dreams, and hypnagogic-hypnopompic experiences? Schizophrenia Bulletin, 42(5), 1098–1109. https://doi.org/10.1093/schbul/sbw076

Williams, J., Merritt, J., Rittenhouse, C., & Hobson, J. A. (1992). Bizarreness in dreams and fantasies: Implications for the activation-synthesis hypothesis. Consciousness and Cognition: An International Journal, 1(2), 172–185. https://doi.org/10.1016/1053-8100(92)90059-J

Yu, C. K.-C. (2001a). Neuroanatomical correlates of dreaming: The supramarginal gyrus controversy (dream work). Neuro-Psychoanalysis, 3(1), 47-59.

Yu, C. K.-C. (2001b). Neuroanatomical correlates of dreaming, II: The ventromesial frontal region controversy (dream instigation). Neuro-Psychoanalysis, 3(2), 193-201.

Yu, C. K.-C. (2003). Neuroanatomical correlates of dreaming, III: The frontal-lobe controversy (dream censorship). Neuro-Psychoanalysis, 5(2), 159-169.

Yu, C. K.-C. (2006). Memory loss is not equal to loss of dream experience: A clinicoanatomical study of dreaming in patients with posterior brain lesions. Neuro-Psychoanalysis, 8(2), 191-198.

Yu, C. K.-C. (2009a). Paranoia in dreams and the classification of typical dreams. Dreaming, 19(4), 255–272. https://doi.org/10.1037/a0017583

Yu, C. K.-C. (2009b). Delusions and the factor structure of typical dreams. Dreaming, 19(1), 42–54. https://doi.org/10.1037/a0014789

Yu, C. K.-C. (2010). Recurrence of typical dreams and the instinctual and delusional predispositions of dreams. Dreaming, 20(4), 254–279. https://doi.org/10.1037/a0020879

Yu, C. K.-C. (2012). Dream Motif Scale. Dreaming, 22(1), 18–52. https://doi.org/10.1037/a0026171

Yu, C. K.-C. (2015). One hundred typical themes in most recent dreams, diary dreams, and dreams spontaneously recollected from last night. Dreaming, 25(3), 206-219.

Yu, C. K.-C., & Liu, T.-W. (2022a). Indigenous Chinese personality and dream content of Hong Kong and Taiwanese people. Dreaming, 32(2), 173–182. https://doi.org/10.1037/drm0000197

Yu, C. K.-C. (2022b). Automated analysis of dream sentiment—The royal road to dream dynamics? Dreaming, 32(1), 33–51. https://doi.org/10.1037/drm0000189

Yu, C., & Shen, H. (2020). Bizarreness of Lucid and Non-lucid Dream: Effects of Metacognition. Frontiers in Psychology, 10, 2946. https://doi.org/10.3389/fpsyg.2019.02946

Zheng, X., & Schweickert, R. (2021). Comparing Hall Van de Castle coding and Linguistic Inquiry and Word Count using canonical correlation analysis. Dreaming, 31(3), 207–224. https://doi.org/10.1037/drm0000173

Zheng, X., & Schweickert, R. (2023). Differentiating dreaming and waking reports with automatic text analysis and Support Vector Machines. Consciousness and Cognition, 107, 103439. https://doi.org/10.1016/j.concog.2022.103439

Appendix A

Most grandiose dream identified by the SVM: Peruvian woman

SVM Grandiosity score = 52.468

We were in a speech class. The teacher was a well-known professional in the field of psychology. In this class each one of the students had to expose a theme that would attract general attention. First it was Mary Ann's (a classmate) turn. She did it very well and was applauded by the audience. The second one to speak was a boy named Edgar (also a classmate, very intelligent, cultured and able, whom I admire especially). He spoke brilliantly about Sophocles's tragedies. Then it was Louise's turn (a friend and classmate). She spoke alright, but was not able to narrow down her topic very well. Afterwards, Roland (a quite intelligent classmate) exposed his topic. I don't remember well what he spoke of or how well he did it. The fifth one to speak was Cindy (a friend and classmate, an intelligent and quite studious girl). But something strange happened with her, because instead of exposing a theme, the same as the others, she began to hum a song and to sing and dance. Together with her performance she presented another great number: it turned out that this girl had the power to transform herself into birds of multi-colored plumage and butterflies of extremely beautiful colors; besides she could transform her surroundings, changing the lighting. I believe it would be hard for me to explain the beautiful picture I had before my eyes. At last Cindy finished her performance and was applauded most of all. The last one to present a theme (which was I) did not fare so well. First, I did not know whether to give a talk or sing as the one before me had done. Finally, I decided on the latter, but in the meantime, the auditorium had been emptied, and the only ones left listening were Louise, the teacher, and Roland. In short, I was in a ridiculous situation, but I did not care and continued to sing until the end. Louise came over and started to make some criticisms; I was silent and accepted it. Going out, I tried to find Cindy. Once I found her, I asked to explain how she had acquired those wonderful gifts. Cindy told me that it was Saint Martin who had given them to her. I continued to ask whether it was the black saint or Jose de San Martin. It was the latter who had given her those gifts as compensation for the effort that Cindy made in her studies and for having an altruistic spirit. But before this Cindy told me that to get in touch with San Martin, one had to go to the cemetery and stand watch by his grave all night. I thought that it was all a fantasy, a realizable dream, but perhaps it could turn into reality. I would give it a try and go to the cemetery and stand watch by the grave of San Martin.

Appendix B

Grandiose dream identified by the SVM: American woman

SVM Grandiosity score = 37.027

I dreamt that I was a famous ballet dancer and was acclaimed by audiences all over the world. Every night I would dance, and at the end of the performance there would be a tremendous ovation and I would receive large bouquets of flowers. All of them carnations. One night I went out on the stage to do my solo and I saw no one in the audience or the orchestra pit. I began to dance anyhow and danced until I feel exhausted. There was a tremendous ovation--from where I didn't know.

Appendix C

Grandiose dream identified by the SVM: Peruvian man

SVM Grandiosity score = 34.876

Last night's dream was strange. In it I dreamed that I dreamed I was in my fourth year in Architecture, the profession I plan to follow, but that I was doing badly on exams and flunked out and couldn't be an architect. Then I awoke and when I took my exams, I got the highest marks and got many prizes. I went on to make beautiful and incomparable works and got many contracts and my fame in America and in the world kept spreading. My works were imitated by all the architects, I created a new style, and defined a new era in construction. Then I was commissioned to do what I called my masterpiece, which would be a building whose base would be at the bottom of the ocean and which would have thousands of stories. I finished the work and went over all the details, but when I got to the last floor, some wood was sticking out the balcony, which was for support, and when I tried to pull it out, I fell into the void and I saw that from each floor they were waving at me on my way down. My dream ends here; that's all I remember.

Appendix D

Most persecutory dream identified by the SVM: Chinese woman

SVM Persecution score = 44.849

In the dormitory where I had lived for three years, two roommates and I were sleeping (three females, the other two were one year younger than me), and a murderer rushes in with a chainsaw, I was the first one to get killed. The data file was re-read and the dream started from the beginning again, I knew that the murderer (biological man, like Jason, also wearing a mask) was coming, so I got out of bed, locked the door and blocked it with a broom, and then hid. Finally, the murderer first killed the people in the next two rooms (screams were heard), and at last, he used the chainsaw to destroy our room, and we were all killed. The data file was re-read the third time, the murderer changed to holding an axe. This time I woke my roommates to hide in the closets, finally the closet I was in was opened first (omission, 4th re-reading data file, it was still an axe, but I don't remember the process, I just remember that I escaped from the door and rushed towards the department office to ask for help, but suddenly felt that it was useless to do anything. I stopped and looked back. I didn't see the murderer, but directly became a black screen and proceeded with the fifth re-reading. Fifth re-reading data file, murderer changed to hold a kitchen knife, this time I hid under the desk. As soon as the murderer entered the center of the room, me and my roommates rushed up with our fruit knives, and then my head seemed to be chopped off. Sixth re-reading data file, two roommates hid in the closet while I was hiding under the desk, and did not dare to make a sound. The murderer first discovered one of my roommates. When he used the kitchen knife to slash my roommate to his heart's content (while the other was trying to stop him), I finally couldn't bear it and grabbed the fruit knife, I stabbed him in the back of the neck, and then smashed his head. There was no re-reading of data file this time, but I seemed to be prosecuted, I ended up hanging myself in jail. No animals appeared in the whole dream. The emotions at the beginning were fear and panic, followed by confusion and wanting to escape, then anger and helplessness (obviously I was angry but couldn't

do anything), and finally despair when the fury reached its extreme (basically all negative emotions).

Appendix E

Persecutory dream identified by the SVM: American woman

SVM Persecution score = 41.200

I was standing in a strange bathroom watching a friend of my mother's washing her hair in the sink upon which a gray kitten was perched calmly watching the proceedings. Suddenly the cat's face contorted in a wild grimace causing the woman to become frightened. Picking up the cat, she threw it into a nearby bathtub which somehow was filled with flames. Horrified I saw the kitten's fur catch fire and the cat slowly begin to burn to death. The woman was instantly remorseful, but her main thought was to put the cat out of its misery by speeding up the burning process and beating the cat over the head. Before the animal had completely disappeared in the flames, I awoke.

Appendix F

Persecutory dream identified by the SVM: American woman

SVM Persecution score = 36.760

I dreamt that I, with a few others, was in a house and people outside were shooting at us. They had guns trained at the windows so that if anyone showed their heads, they would be shot. I wanted to go upstairs to the bathroom, but was afraid I'd be seen and shot. I debated whether I could crawl up and was afraid not. Once someone threw in the window a jelly bomb, it was yellow. It didn't seem to have much effect. This fight had started after the backroom had been set afire. I forget why. I was told to throw water on it as everything was probably killed by now and there was a row of animals charred, but I don't think they were dead. I was a little frightened. There was a burnt crow and I think the other animals were birds also, perhaps vultures. Oh, I was also afraid someone would get close and stick their gun right through the hole made by the jelly bomb and shoot me.

Appendix G

Grandiose dream identified by the SVM but not by raters: Chinese woman

SVM Grandiosity score = 14.751

The song "City in the Sky," that I had heard on YouTube before going to bed, kept on looping in my dream. I dreamed that the singer (Jiang Dunhao) holding a guitar, singing affectionately in front of me. The place in the dream was obscured, the singer was a 21-year-old man, his clothes were the same as I saw on YouTube before going to bed, I had no direct relationship with him. He was just a singer I like very much recently.

Appendix H

Grandiose dream identified by the SVM but not by raters: Chinese woman

SVM Grandiosity score = 9.822

There was a stage at the scene, which was a temporary built. Inside the indoor environment, the white light shined on the stage, the place was relatively bright. There were around 100 people scattered around the seats, some were listening to the speaker on the stage attentively, some were chatting with friends, and some were browsing on their mobile phones. I was on stage giving a speech, I did not know the content of the speech nor the reasons for doing it, then suddenly a wave of inexplicable enthusiasm and power came over me, and I was so good on the stage. I looked down at the stage, all of them were young people whom I had never met, with men and women in civilian clothes. When looking at their expression, making me enjoyed giving my speech even more.

Appendix I

Grandiose dream identified by the SVM but not by raters: Chinese woman

SVM Grandiosity = 9.141

The environment was in the place for lecture, it was very large, like the design of a stadium, I sat in the last row, there were a lot of people. Not familiar with the environment, and it felt like I had only been there for a few times. The person in the dream was someone I don't know in reality, but I liked that person very much in the dream, and his social status was very high. He and I were about the same age, a male, we liked each other. There were no animals appeared. Positive emotions, happy.

Appendix J

Grandiose dream identified by raters but not by the SVM: Chinese woman

SVM Grandiosity score = -33.472, SVM Persecution score = 1.776

Dreamed of watching with a third-person perspective on Hanzo inside Overwatch (a man in his early 30s, we were unrelated, he was just a game character), with a bow destroyed three fighter aircrafts. Then I saw his younger brother Genji (about 20 years old, the body structure was a robot, it's okay, just a game character), and then ruthlessly used a bomb-shaped arrow to blow up the opponent's mechanical body and took away the opponent's katana to chop off the opponent's head, and when I wanted to understand what I had just saw, I woke up.

Appendix K

Grandiose dream identified by raters but not by the SVM: Chinese man

SVM Grandiosity score = -35.219, SVM Persecution score = 4.016

When the dream began, I was in the school playing field, which seemed to be similar but it might also be a campus which I saw on TV or elsewhere. There were many men and women around me, they were of the same age, we were schoolmates in the dream, faces that I had never seen in reality. The playing field broadcast mentioned a game of monster catching people, schoolmates being caught would also become monsters and catch others. When the broadcast announced the game had started, monsters that have never been seen ran out from the school, schoolmates who were caught also became monsters, and people packed together, it was a mess. No other animals appeared, the emotion at the time should be negative (fear).

Appendix L

Grandiose dream identified by raters but not by the SVM: Chinese woman

SVM Grandiosity score = -16.246, SVM Persecution score = -15.313

I dreamed of a Thai male celebrity I liked, he was a little younger than me, I saw him frowning, he was a Thai and didn't understand Chinese, but surprisingly he could speak to me in Cantonese, or I could understand what he said since I knew a little Thai. I felt strange and a little unhappy, because he was frowning at me.... Then there was nothing.... really no more.... I forgot everything else.