REVIEW

Network Diffusion and Technology Acceptance of A Nurse Chatbot for Chronic Disease Self-Management Support : A Theoretical Perspective

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Abstract : Telenursing is one type of telehealth service delivery proposed to resolve the predicted gap between healthcare workforce demand and supply globally. The aim of this article is to explore the 'Nurse Chatbot' for chronic care on the benefits of increasing patient/client access to healthcare information and maximizing the potential of artificial intelligence/AI to bridge the 'demand-supply gap' of human healthcare providers. Moreover, closing this gap through the establishment of a 'Nurse Chatbot' will be innovative, favorably scalable and customizable within a decentralized health network, and potentially sustainable in the new digital economy. Following are the assumptions : 1) *"caring"* communicated textually is highly 'transactive' in chronic disease self-management support/CDSMS for goal agreements between agents and for overcoming the system noise in the form of cross-entropy, perplexity, and information wastage ; 2) 'Nurse Chatbot' is the interlocutor in nursing care and the nursing agency by superpositioning and entanglement ; and 3) possible effects of chatbot-user transactions are information flows, management of health, and patient satisfaction. This article also looks into 'Nurse Chatbot' development for CDSMS, simulation of its diffusion capacity egocentrically, technology acceptance model/TAM to inquire the engagement of users, and possible approaches to ethical and safety issues. J. Med. Invest. 66 :24-30, February, 2019

Keywords **:** *artificial intelligence, nurse chatbot, chronic disease self-management support, network diffusion, technology acceptance model*

INTRODUCTION

The impacts of artificial intelligence/AI to major industries worldwide cannot be ignored. In healthcare, AI has led to the inception of a 'cognitive hospital' and efficient resource management ; knowledge discovery in large datasets and literature for pharmacological and clinical studies ; treatment decisions ; advanced medical diagnostics ; surgical robots ; mobile health technologies for health assessments and medication adherence with chatbots or virtual care assistants ; home care robots ; and public health (1).

Currently, AI seems to push the frontier of the healthcare system capacity on its benefits of delivering reliable and personalized care and promoting self-efficacy to patients versus the number of risks which are articulated ethically and socially (1). AI diverges into multiple technologies that can augment human activities (2) in the form of machine learning, to process and learn with raw data (3) and deep learning (4), to simulate decision-making using complex artificial neural networks. One of its major impacts is on preventive medicine (5) which has become a powerful clinical decision aide tool (6).

Another technology of interest in this article is telehealth. Telehealth can reduce hospital visits of patients by widening their access to healthcare (7) and covering for non-patient care activities (e.g., documentation, prescriptions, etc.) which take much time (2). More importantly, it can address the asymmetry between demand and supply of global healthcare workforce in the future. Unfortunately, only 65 million can be supplied when the need for healthcare workers doubles to 80 million by 2030 (8).The calculated gap is at 20 percent which is around 15 million (2).

Aside from potentially filling the 'demand-supply gap' (2, 8), telehealth has already been an effective alternative healthcare delivery to offer long-term solutions for acute and post-acute care, and chronic disease management (7). On the other hand, technological limitations continue to exist in spite of robust information technology/IT developments for its effective implementation along with regulatory and financial issues (9). On this note, any means of optimization affecting the telehealth ecosystem should lead to *"...more efficient utilization of virtual care solutions"* (7).

Leveraging AI's economic side suggests (re)thinking about the service industry culture of *"growth and productivity performance"* seen in highly technological societies like Japan (10) and the technology acceptance of stakeholders being more dynamic since it is embeddable into various telehealth services. Robotics and automation, internet of things, cloud computing, big data analytics, and AI constitute the fourth industrial revolution-the *"New Digital Economy"* (11), and it stretches to underscore efficiency in business processes. The 'Nurse Chatbot' is innovative, favorably scalable and customizable within a decentralized health network, and may become sustainable in this era following the projected increase in AI use in healthcare and its investment (12).

Moreover, use of chatbots offers a practice leap in nursing care and nurses' skill set towards achievement of *"Healthy People 2020"* as envisioned by The American Nurses Association (13) which aims to increase *"mobility"* (healthcare delivery), *"communication"*

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(information and knowledge exchange), and *"relationships"* (linkages) since telehealth, specifically 'telenursing,' will boost technological competency among nurse practitioners. It is also commendable on the notion of reducing medical costs with technology innovations (7, 13, 14) and theoretically may result to a decrease in 'digital divide' since demands for internet access will increase for the service providers. Emerging technologies (e.g., exceptionally novel or cost-effective solutions that can potentially 'reengineer' the healthcare delivery system) may have great impacts to population health outcomes, healthcare quality, and health equity (13).

The technical feasibility of developing and implementing a 'Nurse Chatbot' is realistic based on the available evidence of chatbot designs and chatbot-delivered/mediated interventions (15). However, not much is known about human-computer/intelligent machine interaction in the 'communicative' dimension (zooming into message content and meaning, networks, and functions to account the logic of connections/causality) which can be intriguingly captured by theorizing : first, the textual properties of *"caring"* transmitted between healthcare chatbots and users ; and second, the formation of ego-centric relationships (i.e. from chatbot to users) to optimize delivery of care.

The aim of this article is to explore the 'Nurse Chatbot' for chronic care on the benefits of increasing patient/client access to healthcare information and maximizing the potential of AI to bridge the 'demand-supply gap' of human healthcare providers.

CARING AS COMMUNICATION (TRANSACTIONS)

The dominant framework of this article comes from the *"Transactive Relationship Theory of Nursing"* /TRETON by Tanioka (16) articulating the relationship between human agent (the 'nursed') and non-human agent (the 'Nurse Chatbot') to address *"caring"*. In this article, the theory will be used for the following : (a) to create the chatbot-based telenursing model of communication ; (b) to describe the diffusion and technology acceptance of the 'Nurse Chatbot' for chronic care ; (c) to elucidate the elements of *"transactions"* (chat history) between conversations, relationships, and interactions (i.e. directed/one-way and undirected/two-way) based on Dubberly and Pangaro's model of second-order cybernetics (17) ; and (d) to address the basic physical paradoxes with the latter against the limitations of early models like 'complexity,' 'unpredictability,' 'general relativity,' and 'entropy' (18) for designing the 'Nurse Chatbot' telenursing system for chronic disease self-management support/CDSMS.

Cybernetic communication by Craig (19) depends on information processing against noise, in the form of noisy data, word meaning ambiguity/uncertainty, multilingual data, etc. (20),which is concurrent with message transmission. Thus, 'redundancy' and 'signal amplification' are necessary. On the other hand, AI-powered chatbots will be efficient in the following : (a) capturing message history (fidelity) ; (b) understanding meanings (semantics) with open-source syntax parsers (e.g., SyntaxNet, ParseySaurus) ; and (c) connecting information across human-to-human or human-to-machine communications (networking). Virtual CDSMS in cases of blood sugar control, blood pressure control, and cancer fatigue and depression seems highly 'transactive,' i.e. metrically in the following : (a) two-way information processing analytics from encoding to decoding of goal and agreement messages (e.g., *n*-gram modeling/computing the word frequencies and correlations) ; (b) 'information wastage ratio' *(Wr)* from Flor's theorem of information overload with 'informatization' (21), expressed as 1 minus information utilization *(IU)* divided by information generation *(IG)* when producing and managing the knowledge base for CDSMS in the system ; and (c) system interference values (e.g., noise, mutual information loss or distortions/uncertainty, cross-entropy, and perplexity).

ROLE OF NURSE CHATBOT

Ideation of a dynamic state when *"knowing persons"* (i.e. technological knowing, designing, and participative engaging) along the Möbius is attributed to Locsin and Purnell (22). Hence, virtually *"knowing persons"* with the 'Nurse Chatbot' poses a similar inclination. Use of quantum theory (in complex networks) to explain the frontiers of real world communication allows the context of (multipartite) 'entanglement' to be visualized in graph states where actors/nodes are independent of physical links/edges (23) in the same dimension. These may be portrayed in space-time by the 'chirality' (opposite rotations) of two entangled Möbius bands (Fig. 1). On the other hand, to understand the 'communicative actions' of agents and how they configure (arbitrarily 'translocate' roles) across two Möbius topologies, the agency framework of organizational communication by Saludadez (24), consisted of upstream agents, interlocutors/middle agents, and downstream agents, is applicable here in order to study the 'edge entanglement' (referring to multidimensional/multilayered interactions) through multiplex network analysis (25).

The 'Nurse Chatbot' can simulate 'autonomy' (judgment) in providing CDSMS (e.g., determining informational healthcare resources, setting goals for behavior modifications based on self-efficacy, and offering options to increase adherence with prescribed medications and health-promoting behaviors based on predicted

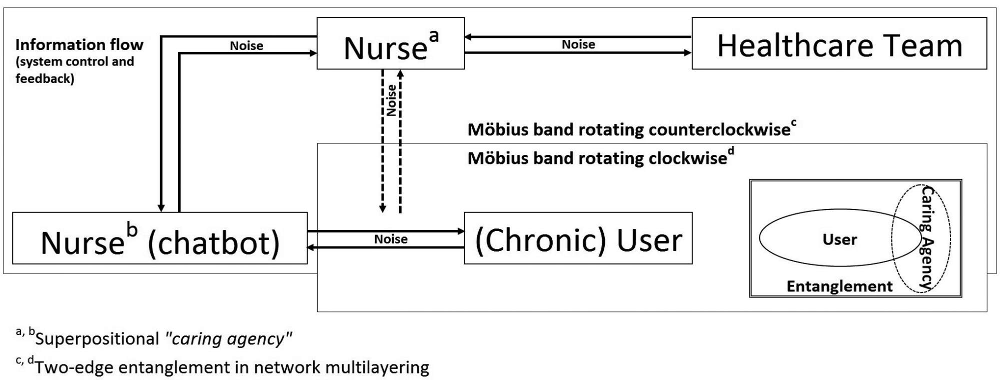


Fig. 1 : Chatbot-based telenursing model for chronic disease self-management support

gaps) by superpositioning and entanglement (Fig. 2) with functions of the *"nursing agency"* (the nurse-led care team), exhibit self-organization (learning from conversations), cognitive and emotional response (reproducing human intelligence and emotions to be comforting), and allow collaborative healthcare management.

EFFECTS OF NURSE CHATBOT

Systematic review of healthcare chatbots by Laranjo *et al.* (15) showed a significant effect in reducing depression. Patients receiving chatbot care are expected to have improved adherence to medication regimen and health-promoting behaviors, and control of symptoms as their self-efficacy increase (e.g., blood pressure control, blood sugar control, and cancer fatigue). Another way to valorize outcomes is by Maslow's Hierarchy of Needs (26) of users (e.g., mental health chatbots have a positive impact on safety, belongingness, and self-esteem). Information flows will be vital to maintain CDSMS. Diffusion, cascades, and 'rewiring' are the important phenomena to analyze quantitatively which will give insight to communication capacity and autonomy of the 'Nurse Chatbot'. Patient satisfaction is theorized as a function of user sentiment and interaction patterns with the chatbot.

Robustness of chatbot operation

Network analysis by Renoust (25) is the suitable approach for the kind of data and the intricacies of high dimensional visualization. According to Tanioka *et al.* (27) humanoid robots can be qualified to care if they can deeply observe, understand/judge, empathize, respond quickly to changing conditions, and personalize care, and normalize the discourses pertaining to ethical and safety issues. Hence, a 'Nurse Chatbot' is expected to mimic them at the interface of the human nurse and the human patient. Conventional designs have to be remodeled by *"humanizing"* the chatbot technology (blend of cognitive and affective algorithms) and *"virtualizing"* (reproducing) the nurse-patient relationship in human-chatbot transactions. Critical in the success of telenursing with chatbots is user satisfaction. Robustness of chatbot operation should be able to approximate real world effectiveness of CDSMS programs. CDSMS decision trees provide codifiable rules for chatbot interventions, e.g., the quasi-experimental study by Hernandez in 2013 (28) to control primary hypertension among industrial workers as programming template.

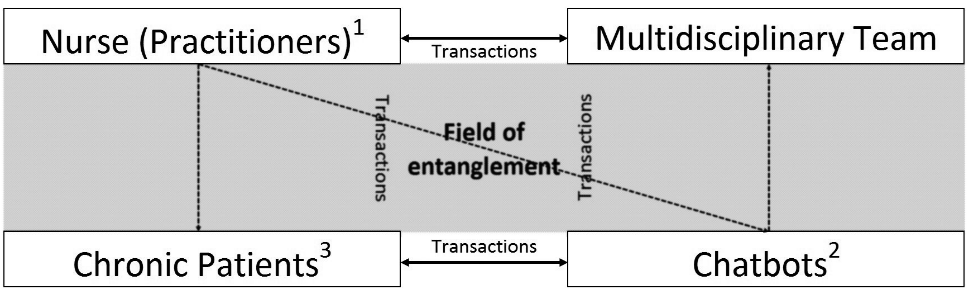
Challenges in chatbot designs

Recent BotAnalytics survey has shown that about 40% of users stop using chatbots after the first encounter and then 25% after the second (29) indicating poor natural language processing/NLP and intelligent response. Third generation chatbots running on neural networks achieve real human responses (30, 31) since the dialogue manager is a hybrid of generation-based and rule-based models. Behavior change communication works well with a persuasive system design (32). Artificial intelligence in the 'Nurse Chatbot' system (Fig. 3) is inspired by Froese's (33) elaboration of biological cognition where the interaction of 'pre-reflective' and 'reflective' processes result to knowledge but is situation dependent (referring to conditions of transactions) based on second-order cybernetics. 'Pre-reflective' process acts on the training data set (e.g., text corpus, chat conversations, feedbacks, etc.). Deep learning functions to extract patterns and to predict such occurrences using a recurrent neural network algorithm. On the other hand, the 'reflective' is NLP which actually means 'distinguishing'/decoding text inputs into word meanings and associations. Message replies are produced by 'reformulating' (encoding) and then 'validating' (decoding) the NLP output with the training data. Overall, system operations adjust to set goals.

Conversational ambiguities can be overcome by employing any of the following combinations : (a) ontology-based system to 'personalize' responses (34) ; (b) context-sensitive generation (35) ; (c) dialogue learning ; (d) implicit feedback (e.g., sentiments in texts) ; and (e) reinforcement learning (36) based on literature. The prototype capitalizes on the advantages of goal-oriented workflows (37), chat-oriented data training and open-domain generated response (38) augmented by latent (input and output) dialog variables (39, 40). To put 'empathy' in CDSMS transactions, the emphatic module (affective/sentiment processing) will recognize emotional cues from human language (41). Chatbot-to-chatbot learning (37) and chatbot system integration with the Internet of Things/IoT (42) are functions to consider for greater convergence.

Ethico-compassionate chatbot behavior

To the knowledge of the author, ego-centric chatbot behavior has not been studied yet . Therefore, diffusion simulation data will be deduced from social (human-to-human) network diffusion and cascade models, e.g., Zhang, Fang, Chen, and Tang (43) ; Lelarge (44) ; and Mehdiabadi, Rabiee, and Salehi (45) which may lead to 'misrepresentation' or 'discourse of representation' and confirmation bias (values are interpreted predilected to the observer ; subjectivity) or 'discourse of understanding,' i.e.imposing separation of subject (caring agents) and object (transactions) to explain the reality (telenursing) instead of weaving it and forging heuristic/intuitive generalizations with scant regard of the multiple dimensions in 'knowing' a phenomenon respectively (46). Dong, Hui and He's approach to structural analysis of chat data (47) is useful on



[1]Upstream agents/virtual operators
[2]Interlocutors/autonomous dialogue agents/change agents
[3]Downstream agents/real world actors/network *"co-operators"*

Fig 2 : Configuration of agents for CDSMS transactions

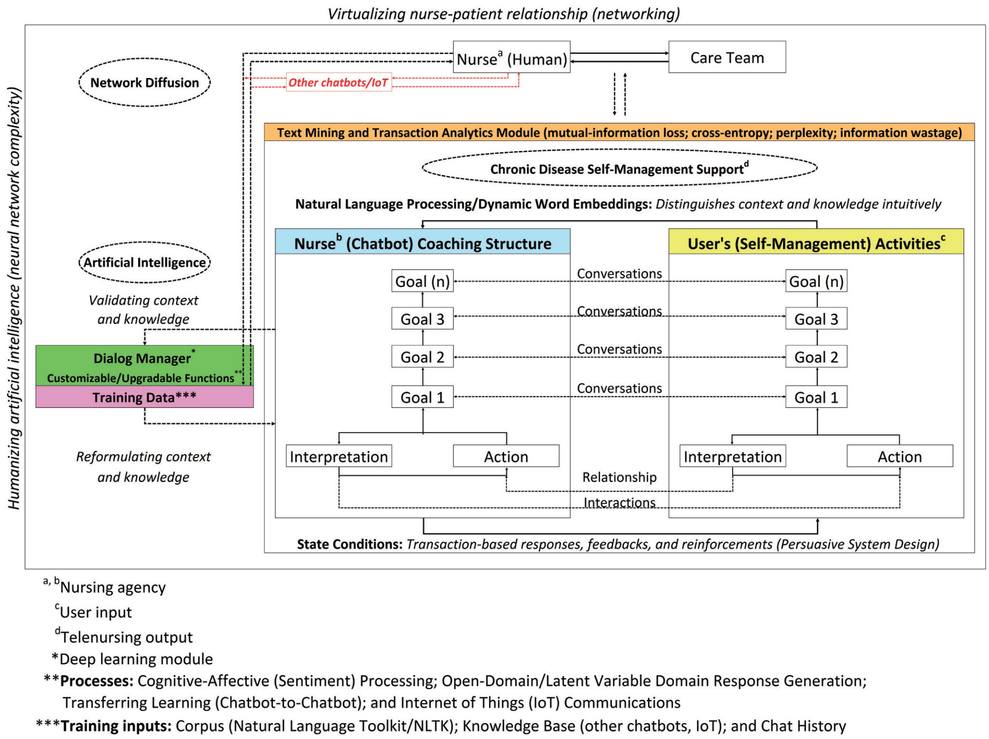


Fig. 3 : 'Nurse Chatbot' architecture, system domains, and operation

inferring 'cross-entropy' (redefined as transmission encoding error ; 'misinformation') and 'perplexity' (redefined as transmission decoding error ; 'disinformation'), e.g., *k*-gram of words (48). Nearest-neighbor statistics provides the analysis of entropy and mutual information between agents (49). 'Mutual Information Loss,' in theory, surges from [uncontrolled] informational uncertainties for producing the recursive, 'nudging' actions in order to change or target patient/client (problematic) health behavior(s) during CDSMS transactions (as entropy), unharmonized disagreements (as perplexity), and information overload. The degree of perplexity is inversely related to the amount of information exchanged, i.e. lowering perplexity means increasing information (50) to decrease uncertainty in transactions while increasing 'information wastage ratio' (21) on the other side. These assumptions, when validated, will expose the complexity and relativity of the phenomenon of *"caring"*.

Converting the Technology Acceptance Model/TAM into structural equations, the way Erasmus, Rothmann, and van Eeden (51) have demonstrated, will be prudent not only for calculating probabilistic adoption of the 'Nurse Chatbot' but also for testing variables' state transitions with Petri nets/agent-based modeling, stochastic 'decay,' and resistance to information flow over time (e.g., knowledge, regression with CDSMS, etc.). TAM elements could be manipulated to act as gatekeepers and then visualized in a multilayer network. It may permit simulation of the amount of information (e.g., bytes, *n*-gram) significant to inform and to persuade users based on the equation by Flor (21).

Three out of eleven ethical themes surfacing from AI technologies echo global concerns, namely : 'Privacy and Misuse,' 'Transparency,' and 'Abuse and Human Rights' (26). In the case of 'Nurse Chatbot,' the following solutions should be validated respectively : data encryption and artificial neural network-based cybersecurity ; informed consent/explicit system documentation/full disclosure of chatbot decision support/monitoring of information asymmetries ; and 'Bad Word Filter' in NLP algorithm.

Chatbot design and operation are covered in the 'Ergonomics of Human-System Interaction' quality measures by the International Organization for Standardization/ISO, stipulated as 'usability' (ISO 9241-11) in terms of : 'effectiveness' (functionality and humanity, e.g., passing the Turing test of intelligent behavior) ; 'efficiency' (performance) ; and 'satisfaction' (affect, ethics and behavior, and accessibility) according to Radziwill and Benton's findings (52).

CONCLUSION

Feasibility of a 'Nurse Chatbot' for chronic care is worth exploring on the benefits of increasing patient/client access to healthcare information and maximizing the potential of AI to bridge the gap between demand and supply of human healthcare providers, particularly in the delivery of a 'robust' level of CDSMS via novel telenursing (service) model as proposed in this article. The design features ascribed to what constitutes a 'Nurse Chatbot' and how it will work is integrative at the current level of innovation in an attempt to humanize *"caring"* by non-human agents, which is an *"anthropomorphistic"* (26) disposition with AI technologies ; and to replicate the properties of *"caring"* communicatively via telenursing in the context of combining cybernetics and quantum network theory. At the moment, challenges do not just glean rigors of explicit coding mounted on the frame of computing and nursing rather are forked between technology acceptance, possible outcomes, and ethics as 'metadiscursive' among stakeholders. Hence, the spectra of interests and opportunities prompting diffusion of AI (in multisector landscape) will always be in a state of flux. Nevertheless, it is plausible to inquire both theoretical dissonance/divide and polarization among scholars regarding the *"caring"* dimension(s) in the presence of AI. The 'Nurse Chatbot' and its implementation could be a metaphor of *"cross-fertilization"* of nursing beyond the neighboring sciences, creating borderless fields of knowledge instead of collecting knowledge into silos and isolating it within the field.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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