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# A Robot to Provide Support in Stigmatizing Patient-Caregiver Relationships

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**Abstract**

This paper introduces a computational model and action-selection mechanism that allow for a robot to support healthier interactions between Parkinson's patients and their caregivers. Patients' caregivers will sometimes stigmatize the patients because of a condition known as an expressive mask. Our computational model identifies problematic states in the patient-caregiver relationship. After the problematic relationship dynamics have been identified, the robot action-selection mechanism chooses an intervention to help to ameliorate the highest-priority relationship issue.

## Introduction

Early-stage Parkinson's disease patients are often afflicted with a condition known as an "expressive mask", which limits their ability to be expressive across all nonverbal communication channels (Tickle-Degnen and Lyons, 2004; Tickle-Degnen, Zebrowitz and Ma, 2011). This lack of nonverbal expressivity leads even experienced caregivers to make negative attributions about patients, seeing them as more depressed, less extroverted and less cognitively competent when compared to patients without masking.

Our lab has previously proposed that a robot could help to support healthier interactions between Parkinson's patients and caregivers (e.g. Pettinati and Arkin, 2015). This paper formalizes Parkinson's patient-caregiver relationship dynamics and enumerates problematic relationship states where patients are at risk of indignity. It introduces a computational model that identifies these states and an action-selection mechanism that allows for a robot to choose interventions that support the amelioration of these states.

The following section gives a brief overview of robotics research related to enhancing human-human relationships and a relationship-focused mediation framework that provides the foundation for the computational model and action-selection mechanism. The third section explicates the computational model and action-selection mechanism.

## Related Work

There has been limited research into how robots can help the functioning of human groups and dyads. Jung (2016) found that the same socio-emotional dynamics that predict lasting marriages predict success for engineering teams completing class projects. Teams that balanced the positive and negative affect they expressed and voiced little hostility during fifteen-minute conflict interactions were successful in producing quality final products (Jung, 2016). Jung suggested that a robot could help balance positive and negative affect and repair hostility to better group functioning.

Jung et al. (2015) showed that a robot that verbally responded to a confederate's insult aimed at a participant during a group task could repair the negative feelings the participant had for the confederate. Hoffman et al. (2015) showed a peripheral robotic lamp could use nonverbal cues to limit the hostility displayed by arguing married couples.

These studies show the potential for robots to change the emotional dynamics within human-human relationships during strained interactions. We want to recognize dynamics in patient-caregiver relationships that undermine patient strength and have a robot act to preserve patient dignity. We can employ insights from Transformative Mediation, a relationship-focused practice, to guide the identification of problematic dynamics and to choose interventions.

Bush and Folger (2010a) describe the theoretical underpinnings of this framework. Negative conflict is conceptualized as an interaction where both parties experience a weakened self (shame) and alienation from the other (a lack of recognition or empathy for the other). Transformative mediators support empowerment shifts within the individuals and recognition shifts between the individuals.


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Weakness is characterized by a lack of clarity and/or feelings of inadequacy when it comes to handling the situation. An individual who is alienated from the other sends messages that say he/she does not understand and/or does not want to understand the other (Bush and Folger, 2010b).

We formalize these problematic relationship states in the following section. We introduce a computational model that recognizes situations when a robot should support the relationship. An action-selection mechanism picks an appropriate intervention using the active relationship states.

## Computational Model

The patient-caregiver relationship is a hierarchical relationship. The patient entrusts the caregiver with her physical wellbeing; the patient has to trust that the caregiver will act in her best interests. The caregiver is in a higher-power position (H), while the patient is in a lower-power position (L). Our robot (R) is interested in intervening in the relationship when the patient's dignity is threatened; otherwise, the relationship should be allowed to develop naturally. The robot is playing a supportive role

The relationship has three actors, A = {H, L, R}, where H is the high-power dyad member (caregiver), L is the low-power dyad member (patient), and R is the robot. H and L give each other direct attention, while R's presence is acknowledged at the interaction's periphery with passing glances. When intervening, R is attentive. See Figure 1.

We consider a partial theory of mind of each human actor that allows us to enumerate problematic relationship states in the following subsection. The mental states of both human actors and the robot's representation of these mental states are defined in Table 1. Whether or not a problematic relationship state is active depends on the robot's representation of the mental states. As described below, problematic relationship states are mapped onto by percept values that are indicative of active mental states in one or both human parties that threaten L's dignity.

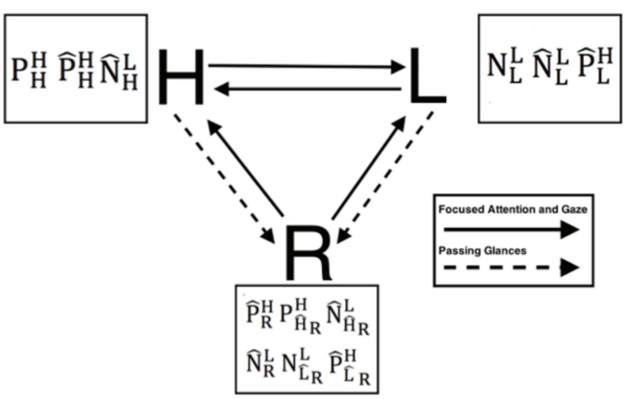


*Figure 1: Actors' relationships and representations*

The following subsection enumerates the relationship state space and presents a computational model through which a robot can recognize states of dissatisfaction. The second subsection enumerates behaviors that address each relationship state and an action-selection mechanism that supports a healthier relationship. An overview of the computational model appears in Algorithm 1. Each term and function used in Algorithm 1 is elaborated in the subsections. Note the enacted intervention ($m_{ik}$) could be to do nothing. The relationship may not require agent support.

| | |
|---|---|
| **H's Mental State** | $\{P_H^H, \hat{P}_H^H, \hat{N}_H^L\}$ |
| | $P_H^H$ - H's positive responsiveness toward L of which she is consciously aware (attention and uplift) |
| | $\hat{P}_H^H$ - H's estimate of how she is conveying these positive emotions. |
| | $\hat{N}_H^L$ - H's estimate of L's negative response toward herself (signs of disengagement and desire to withdraw). |
| **L's Mental State** | $\{N_L^L, \hat{N}_L^L, \hat{P}_L^H\}$ |
| | $N_L^L$ - L's negative thoughts toward the self of which she is consciously aware. |
| | $\hat{N}_L^L$ - L's estimate of how she is conveying these negative emotions. |
| | $\hat{P}_L^H$ - L's estimate of H's positive emotions toward her. |
| **R's Representation of Mental States** | $\{\hat{P}_R^H, P_{\hat{H}_R}^H, \hat{N}_{\hat{H}_R}^L, \hat{N}_R^L, N_{\hat{L}_R}^L, \hat{P}_{\hat{L}_R}^H\}$ |
| | $\hat{P}_R^H$ – R's estimate of H's displayed positive affect. |
| | $P_{\hat{H}_R}^H$ - R's estimate of H's conscious positive affect. |
| | $\hat{N}_{\hat{H}_R}^L$ - R's estimate of H's responsiveness to L's negative emotions. |
| | $\hat{N}_R^L$ - R's estimate of L's displayed negative affect. |
| | $N_{\hat{L}_R}^L$ - R's estimate of L's conscious negative affect. |
| | $\hat{P}_{\hat{L}_R}^H$ - R's estimate of L's responsiveness to H's positive affect |

*Table 1: Definitions of Actors' Representations*

**Intervention Algorithm**

```
Define: Percept-Generating Functions F <f_1,..., f_m>
        Set Active States Function g
        Behaviors B <β_empathy, ... , β_maintain>
        Coordination Function C
Input: Pointers to Sensor Objects S <s*_1,...,s*_n>
       Pointers to Percepts P <p*_1,...,p*_m>
       Pointers to State Vector X*

//Step 1: Identify Active Relationship States
For each s_i ∈ <s_1,..., s_n>
    s_i->start( )
For each f_i ∈ <f_1,..., f_m>
    Spawn thread f_i(S, p_i) //f_i(S)→ p_i continually
Spawn thread g(P, X) //g(P)→ X continually

While TRUE
    //Step 2: Choose Intervention - note that the chosen
    //        intervention could be to do nothing

    //Given the active states, set possible interventions.
  Initialize M //Potential behavioral manifestations
  For each state x_i ∈ X
     If x_i == 1 //is active
        M.i = β_i(x_i) //a predefined set of behavioral
                       // manifestations to ameliorate state i
     Else
        M.i = Ø
     End If
  End For

    //Choose specific intervention (m_ik)
    m_ik ← C(M)

    //Step 3: Carryout Intervention
  Enact m_ik //The intervention m_ik could be to do nothing
End While
```

*Algorithm 1: Overview of the Intervention Algorithm*

## Identifying Problematic Relationship States

H and L's relationship may be in an acceptable state (where mutual satisfaction exists) or in one or more states of dissatisfaction. Let X be the relationship state space.

Dissatisfaction exists if H has little positive affect for the other, i.e. H is inattentive (e.g. averts her gaze) or demonstrates aggression (e.g. raises her voice) toward L ($x_{insensitivity}$). The relationship is also strained if L is experiencing strong negative affect, i.e. is withdrawn from the other (e.g. uses few utterances) or aggressively pushes H away (e.g. glares at H) ($x_{negativity}$). It is problematic if H inappropriately expresses her positive affect ($x_{intrapersonal\_discordance\_high\_positive}$) or if L inaptly presents her negative affect ($x_{intrapersonal\_discordance\_low\_negative}$). H or L may have conflicting affect cues or fully curtail expression.

The dyad members need to be responsive to each other's mental states with respect to these emotions. Therefore, the relationship is in a state of dissatisfaction if L is not receptive to H's positive affect toward her ($x_{interpersonal\_discordance\_high\_positive}$) or if H does not respond to L's negativity ($x_{interpersonal\_discordance\_low\_negative}$). If H is attentive and uplifts L, L is not overly negative, each member of the dyad is expressing herself accurately, and the dyad members are responsive toward one another, then the relationship is said to be in an acceptable or satisfactory state ($x_{acceptable}$). Each state is binary, either present or not.

$$X = \{x_{insensitivity}, x_{negativity}, x_{intrapersonal\_discordance\_high\_positive}, x_{intrapersonal\_discordance\_low\_negative}, x_{interpersonal\_discordance\_high\_positive}, x_{interpersonal\_discordance\_low\_negative}, x_{acceptable}\}$$

R must be able to identify which states are active at a particular time t. Let S be a vector of n sensors that allow R to interface with the environment, and let P be a vector of m percepts, abstractions of sensor readings, that indicate the presence of certain states. Let $F = \{f_1,\ldots,f_m\}$ be a set of functions such that $f_i(S) \rightarrow p_i$. Each function $f_i$ in the set F maps a sensor's or sensors' readings that fall within a specified sliding window of time to a specific percept $p_i$ where $p_i$ is one of the m total percepts. Algorithm 2 shows the implementation of a function $f_i$.

```
Function f_i
Input: Pointers to Sensor Objects S <s*_1,...,s*_n>
       Pointer to Percept i <p*_1>

Initialize D //Holds raw data
While TRUE
    For each sensor s_j associated with percept p_i
        Spawn thread
        D.s_j = s_j->read_buffer()
    End For
    Wait For each s_j read
    p_i->write(y_i(D)) //y_i - predefined mapping from D to p_i
End While
```

*Algorithm 2: Mapping Sensor Data to Percepts*

We also define a function $g(P) \rightarrow X$, which maps the entire percept vector, which contains the current percept values at time t, to the state space (X). Algorithm 3 shows the implementation for g. Figure 2 (top) shows the data flow from the sensors to a vector that indicates active states.

```
Function g
Input: Pointer to Percept Vector P*
       Pointer to State Vector X*

While TRUE
    Initialize activeStates = {1,1,1,1,1,1,1} //All states active
    For each state x_i ∈ X
        For each percept p_i ∈ P related to state x_i
            //conditions_met() – lookup table – can state be
            //active given percept value
            If conditions_met(x_i, p_i) == FALSE
                activeStates.x_i = 0
            End If
        End For
    End For
    X->write(activeStates)
End While
```

*Algorithm 3: Mapping Percepts to Active States*

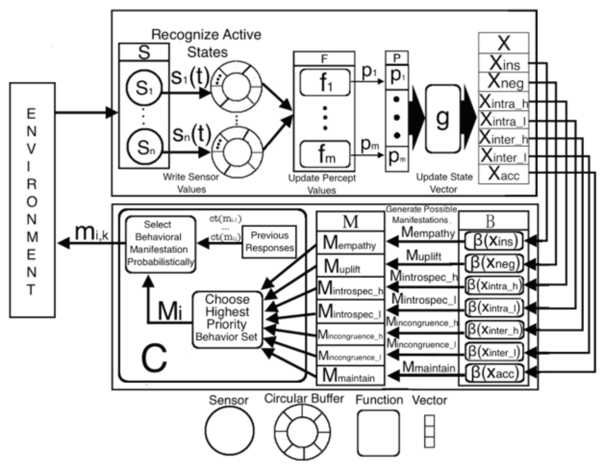


*Figure 2: Data Flow from Sensors to Intervention*

## Interventions to Ameliorate Relationship States

Each state in the computational model is addressed by a certain robot behavior. R must encourage empathy if percept values indicate H is inattentive or aggressive. If L is overly negative, R must act to uplift L. When H or L's expression lacks or includes conflicting affective cues, R must encourage introspection. If a dyad member's response to the other's affective expression is incongruent with the other's mental state, R must reduce this incongruity. These behaviors are summarized in Table 2 (next page).

B is a vector that contains R's available behaviors. Let $\beta_i$ be a single behavior in the vector B. Each of R's behaviors can manifest in numerous ways. Let M be a vector that contains the sets of possible manifestations for each behavior. The set $M_i$ is one set in the vector of sets M; this set contains the potential manifestations for the corresponding behavior ($\beta_i$). That is, $\beta_i(x_i) \rightarrow M_i$. The set $M_i = \{m_{i1}, \ldots, m_{ij}\}$ where $m_{ik}$ is specific manifestation of behavior i that addresses the state $x_i$.

R chooses one behavioral manifestation ($m_{ik}$) from the possible ways of responding to current situation. C denotes a coordination function such that $C(M) \rightarrow \{m_{ik}\}$. The coordination function maps the possible behavioral manifestations at the current time (M) to a single behavioral manifestation (the response at that time). Algorithm 4 shows the selection process. The algorithm chooses the most important behavior to enact given the active states. It selects a single manifestation of this behavior using a weighted roulette wheel. It updates the weights and returns the intervention. The bottom of Figure 2 shows the data flow from when the set M is determined to when the robot intervenes.

| Relationship State | Associated Robot Behavior |
|---|---|
| H is Insensitive (Inattentive or Intimidating/Aggressive) toward L ($x_{ins}$) | Encourage Empathy in H |
| Pronounced Negativity (Withdrawal or Aggressiveness) in L ($x_{neg}$) | Uplift L |
| Internal Discordance in H ($x_{intra\_h}$) | Encourage Introspection in H |
| Internal Discordance in L ($x_{intra\_l}$) | Encourage Introspection in L |
| Incongruence Between H's Positive Affect Toward L and L's Responsiveness ($x_{inter\_h}$) | Reduce the Incongruity Between H's Positive Affect Toward L and L's Responsiveness |
| Incongruence Between L's Negativity and H's Responsiveness ($x_{inter\_l}$) | Reduce the Incongruity Between L's Negativity and H's Responsiveness |
| Acceptable ($x_{acc}$) | Maintain Relationship |

*Table 2: Robotic Behaviors to Ameliorate Problematic States*

```
Function C
Input: Potential Behavioral Manifestations M
Output: Behavioral Manifestation to Enact mik

//Step 1: Choose highest priority behavior set
1. maxPriority = 0  //Initialize maximum priority
2. maxSet  = M.1 //Max priority behavior set
3. For each set M.i ∈ M   //where Mi = {mi1,...,miN}
4.    If priority(M.i) > maxPriority //a predefined lookup table
5.        maxPriority = priority(M.i)
6.        maxSet = M.i
7.    End If
8. End For

//Step 2: Choose specific behavioral manifestation
9.  Initialize weight = {0,...,0}
10. For each mij ∈ M.i
11.     weight.mij = probability(mij) //lookup table - probability
12. End For
    //Choose intervention using weighted roulette wheel
13. mik = weighted_roulette_wheel(weight)

//Step 3: Update probability lookup table values
14. count(mik) = count(mik) + 1 //times mik has been enacted
15. For each mij ∈ M.i
      //update values in lookup table with predefined
      //probability distribution, p(mij|count(mi1),...,count(mij))
16.   probability(mij) = p(mij|count(mi1),...,count(mij))
17. End For

//Step 4: Return Intervention
18. Return mik
```

*Algorithm 4: Coordination Function to Choose Intervention*

## Conclusion and Future Work

This paper introduced a computational model and action-selection mechanism that allow for a robot to preserve the dignity of patients when they are involved in stigmatizing interactions with their caregivers. The states identified in our computational model as well as the behaviors that address these states are rooted in literature from transformative mediation. We are in the process of setting up and executing a study to help validate this model.

This is a two-stage study. The first stage involves validating the model's relationship states. We are gathering a corpus of data where the relationship states are identifiable to human coders. We will show that an artificial intelligence is able to identify these states with high precision and recall when treating the human labeled data as ground truth. In the second stage of the experiment, we will have an autonomous robot identifying the states and intervening to ameliorate the states. We expect the robot to support more open, clear, and positive communication in the dyad.

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